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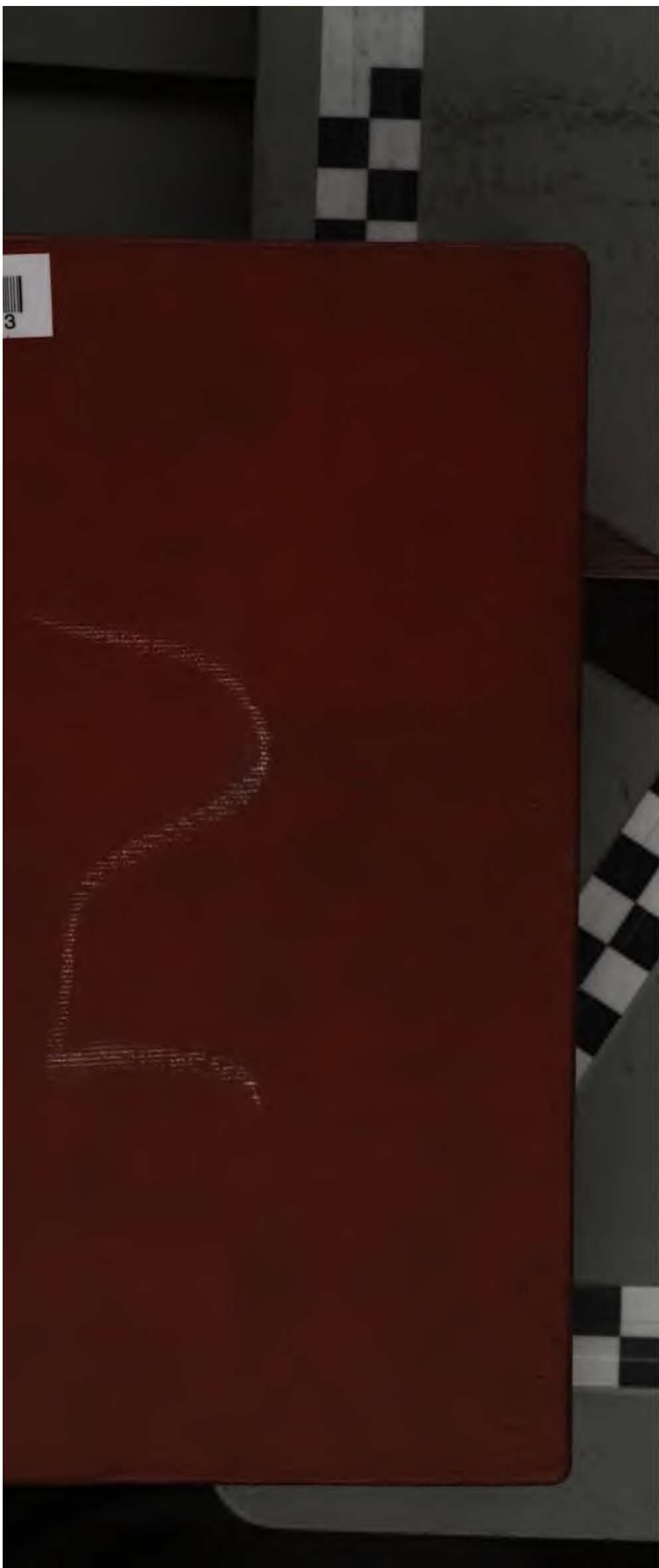
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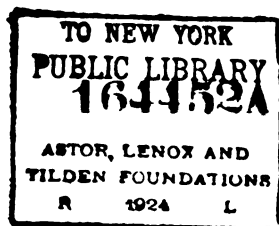
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THE Cyclopedia of Engineering is compiled from the most practical and comprehensive instruction papers of the American School of Correspondence. It is intended to furnish instruction to those who cannot take a correspondence course, in the same manner as the American School of Correspondence affords instruction to those who cannot attend a resident engineering college.

¶ The instruction papers forming the Cyclopedia have been prepared especially for home study by acknowledged authorities, and represent the most careful study of actual shop needs and conditions. Although primarily intended for correspondence study, they are in use as text books by Columbia University, Lehigh University, Iowa State College, the University of Maine, the U. S. Government in its School of Submarine Defense, the Westinghouse Companies in their Shop School, and for reference in the leading colleges, shops and public libraries.

¶ Years of experience in the shop, laboratory, and class-room have been required in the preparation of the various sections of the Cyclopedia. Each section has been tested by actual use for its practical value to the man who desires to know the latest and best practice in the shop or engine room.

¶ Numerous examples for practice are inserted at intervals; these, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a text book with a reference work.

¶ Grateful acknowledgment is due to the corps of writers and collaborators, who have prepared the many sections of this work. The hearty co-operation of these men—engineers of wide practical experience and acknowledged ability—has alone made these volumes possible.

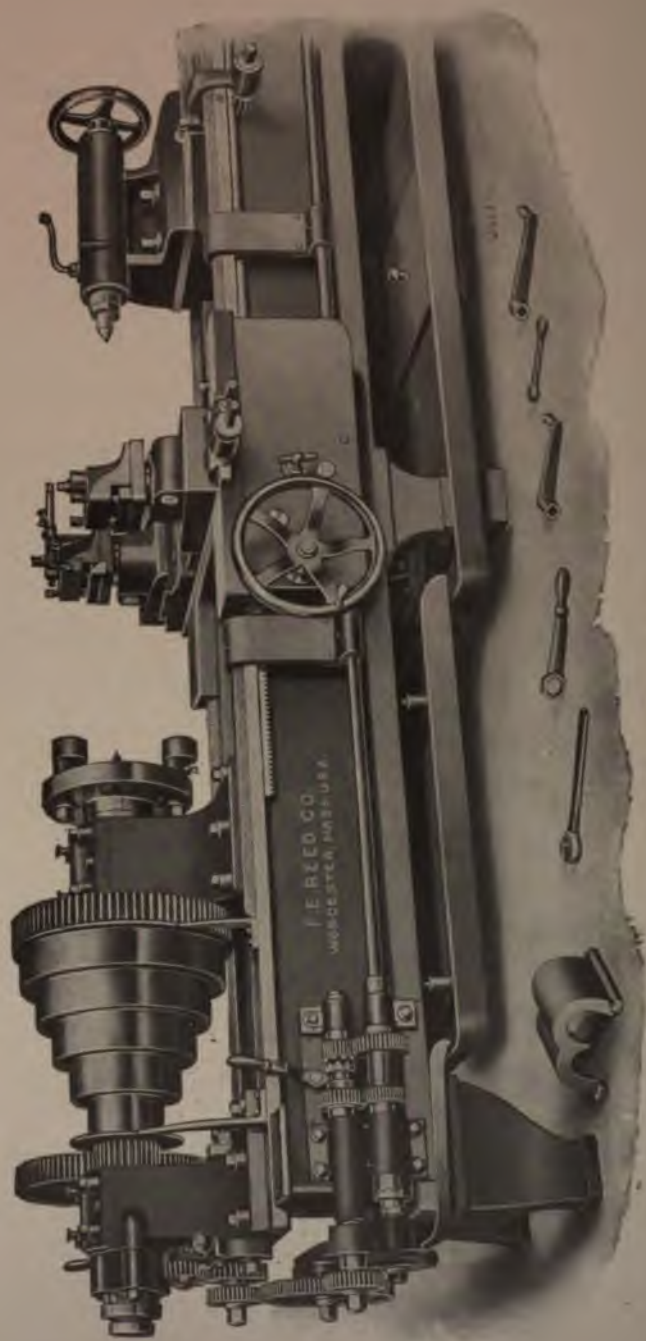
¶ The Cyclopedia has been compiled with the idea of making it a work thoroughly technical yet easily comprehended by the man who has but little time in which to acquaint himself with the fundamental branches of practical engineering. If, therefore, it should benefit any of the large number of workers who need, yet lack, technical training, the editors will feel that its mission has been accomplished.



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MACHINE SHOP WORK.

PART I.

MACHINE shop work is usually understood to include all cold metal work in which a portion of the metal is removed to make the piece of the required shape and size either by power-driven or hand tools. However, there are some branches of cold metal work, such as sheet-iron work and coppersmithing, that are not included in machine shop work.

HAND-OPERATED TOOLS.

As the hand-operated tools are much simpler, and as the operations performed with them are in every case more typical, their description and use should precede that of power-driven tools. It should be clearly understood, however, that machine shop practice involves the use of both classes at the same time. Even hand tools are not used in the same order on different classes of work; it is, therefore, impossible to describe them in the order of use. Simplicity of construction and operation will be the guide for treatment in the following pages.

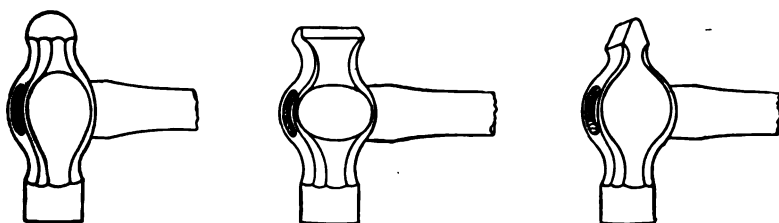


Fig. 1.

The machinist uses **hammers** of three shapes: ball pene, cross pene, and straight pene. See Fig. 1. The first named, the ball pene, is the most common; it varies in weight from four ounces to three pounds. The cross and straight pene hammers vary from four ounces to two pounds and are used principally in riveting. All hammers are made from a good grade of cast steel,

hardened, and drawn to a blue color at the eye and a dark straw on the face and pene. The eye is elliptical in shape, and the handle is fastened by driving wedges, either wood or iron, into the end of the handle, thus spreading it to fill the eye. The handle is of hard wood, preferably hickory, and of a length suited

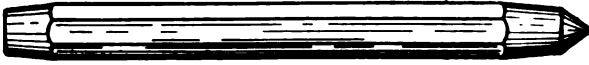


Fig. 2.

to the weight of the hammerhead. When the handle is properly inserted, the axis of the head stands at right angles to the axis of the handle.

Soft hammers are used for striking heavy blows where the steel hammer would bruise the metal or mar the surface. They are made of rawhide, copper, or Babbitt metal, and vary in weight from six ounces to six pounds. They are subject to rapid wear, but are indispensable in setting up and taking down machinery. Those of metal are so constructed that the soft metal can be re-cast in the handle.

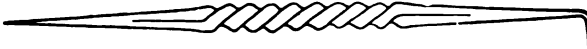


Fig. 3.

The *prick punch*, Fig. 2, is made of cast steel with a hardened conical point of about 60 degrees. It is about $3\frac{1}{2}$ inches long and $\frac{1}{4}$ inch in diameter. It is used for making very small holes at intervals of about $\frac{1}{2}$ inch on a line.

The **center punch**, also shown in Fig. 2, is made of the same general appearance as the prick punch, but is about 5 inches long, $\frac{1}{2}$ inch in diameter, and has a point of about 90 degrees. The principal use is to make center holes marking the centers on the ends of pieces to be turned.

Both prick punches and center punches are usually made of

hexagonal steel; but if round stock is used, the grip should be fluted or knurled to prevent slipping in the fingers.

The **scriber** or **scratch awl**, Fig. 3, is made in many forms, but consists essentially of a cast-steel rod about 8 inches long and $\frac{3}{16}$ inch in diameter, with a long, slender, hardened point at each end; frequently one point is bent at right angles to the shank. As the name indicates, this tool is used for marking lines on the surface of metal.

The **surface gauge** is used in laying out work for the bench, lathe, or planer. The ordinary form consists of a heavy base, an upright, and a scriber or scratch awl; the upright being firmly fastened to the base. In the universal gauge, the upright is pivoted at the base so that it may be used at any angle. In some forms the base is grooved in order that the gauge may be used on cylindrical work as well as on flat surfaces. See Fig. 4.

To use the gauge, the part of the work to be laid out must be prepared so that lines drawn on the surface will show distinctly. A rough or unfinished surface is covered with chalk, a finished or bright surface should be copper-plated by applying a thin coating of copper sulphate solution with a brush or a piece of waste. The work and gauge are then placed on a true surface and the scriber adjusted to the desired height. The line is drawn by moving the surface gauge along on the true surface, keeping the point in contact with the work. After scribing the lines, it is well to place light prick punch marks at frequent intervals along the lines, so that the position may be found if the chalk or copper sulphate becomes effaced.

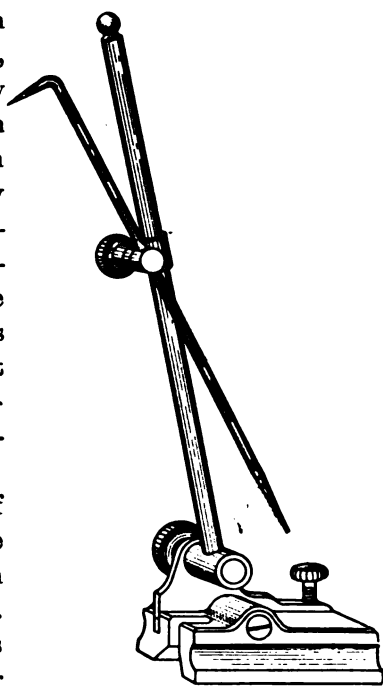


Fig. 4.

The **straight edge** consists, in its simplest form, of a thin flat piece of steel, generally unhardened, with accurately finished straight edges. The very small sizes used in fine work are sometimes made with a hardened knife edge. A non-conducting

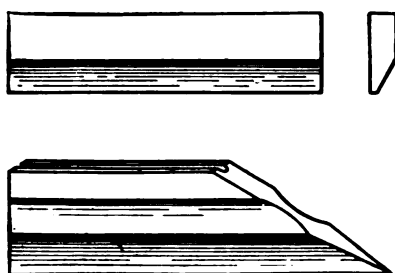


Fig. 5.

handle is sometimes used with the small sizes to prevent distortion from the unequal heating due to handling. The short lengths used for ordinary shop purposes have one edge beveled, and are thick enough to avoid bending. See Fig. 5. The larger sizes, from three to ten feet or more in length, are usually made of cast iron with

one finished edge. The metal is so distributed as to combine lightness with great rigidity, the tendency of the ends to drop being resisted by the truss-like form of the casting shown in Fig. 6. The flat form is used, in connection with the scribe, to draw accurate straight lines on plane surfaces. All styles are used to test the truth of plane surfaces by placing the straight edge on the surface to be tested in not less than the six positions shown in Fig. 7.

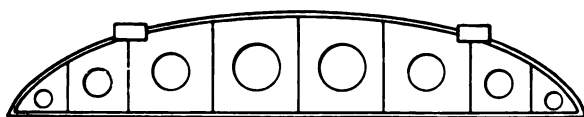


Fig. 6.

For drawing lines and laying off distances on curved surfaces, such as shafts, a combination of two straight edges, or a straight edge and a rule, is used. This is often called a *key seat rule* because its chief use is laying out keys on shafts. However, many machinists call it a "box-rule." It is usually made in one piece, although some manufacturers provide clamps by which the two separate pieces are held at right angles to one another. A more simple combination is shown in Fig. 8, the second scale being represented by two special clamps.

The simplest form of square, called the *flat square* (Fig. 9), is a combination of two straight edges at right angles. This is a useful form where the square is laid on the work. One blade

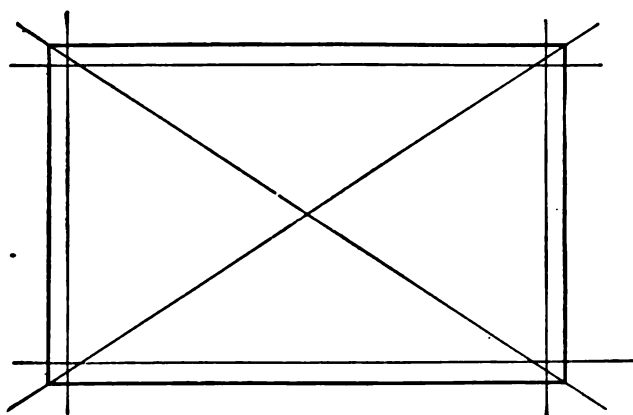


Fig. 7.

is usually graduated on the inner edge, and the other on the outer edge. The flat square is not hardened.

The **try square**, shown in Fig. 10, consists of a beam and a blade at right angles. The beam is much thicker than the

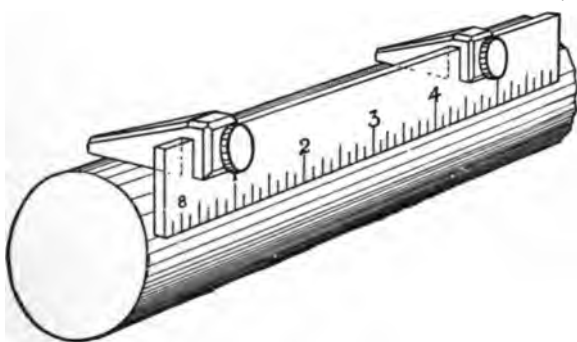


Fig. 8.

blade and somewhat shorter. Try squares are made both unhardened and hardened. The unhardened form has graduations on one edge, and is called the graduated try square. The hardened type always has a hardened blade, sometimes a hardened beam as well, and is not graduated.

The try square is used as a guide to draw lines at right angles to each other and to given surfaces; to erect and test perpendiculars to plane surfaces; to test the truth of a given surface at right angles to another surface; in short, it is used wherever an accurate measurement of 90° is required. When used for testing the relation of two surfaces, the beam is pressed closely against the correct surface, and the blade brought carefully down to the

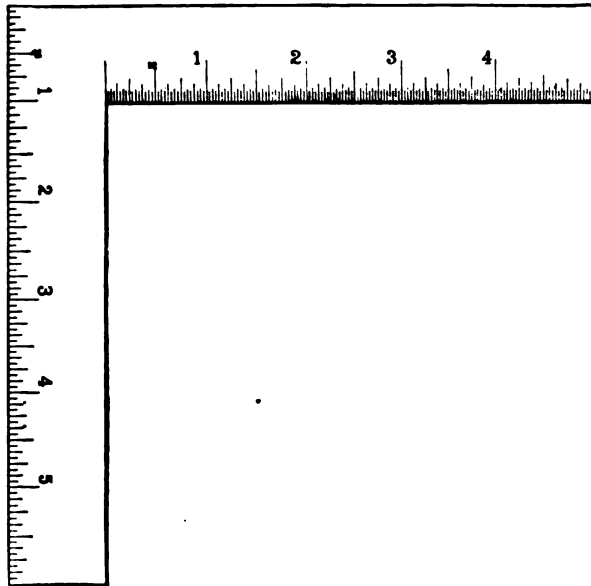


Fig. 9.

surface under consideration. This does not prove more than that a line at the particular point tested is or is not at right angles to the true surface. By using the blade as a straight edge parallel to the true surface, errors in that direction may be corrected and the surface be made plane.

In many cases it is necessary to test the relation of lines and surfaces which are not at right angles to each other. For this purpose a **bevel** is used in which what corresponds to the blade of the square is made adjustable. Its construction is seen in Fig. 11, and its use is similar to that of the square.

The bevel can be adjusted only by direct application to lines or surfaces having the proper angular relation. It often happens that such adjustment is not feasible, and therefore a registering device, in the form of a graduated arc, is applied to the bevel, making what is known as a **protractor**, shown in Fig. 13. This tool can be used to find the angular relation in degrees or to produce that relation by setting to the proper point on the graduated arc.

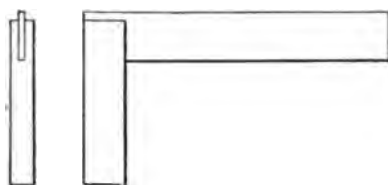


Fig. 10.

As the center of a circle is found at the intersection of any two diameters, an instrument for readily finding that point is a great convenience. In Fig. 12 is shown a combination of straight edge and square called a **center square**, which accomplishes this

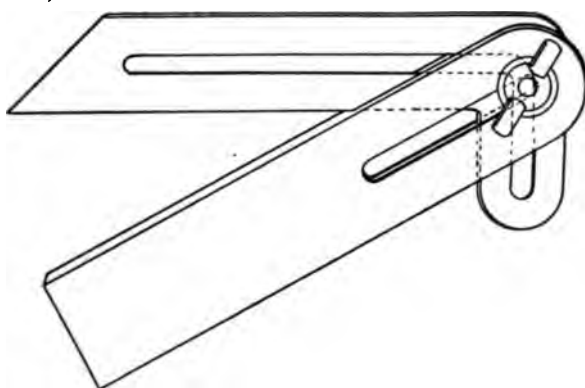


Fig. 11.

result. As one edge of the rule bisects the angle of the square, it is evident that a line drawn by that edge passes through the center of any circular piece to which the square is applied. Centering the ends of round bars or circular work of any kind is the principal use of this tool.

The center square, bevel, and protractor are furnished in a combination set as shown in Fig. 14. The ability to change the length of the blade is one of the great benefits of this construction.

MEASURING TOOLS

The testing tools thus far described are used for comparing the angular relation of lines and surfaces, and may be called tools for angular measurement. We now turn to the consideration of instruments for measuring distances and sizes, or tools for linear measurement.

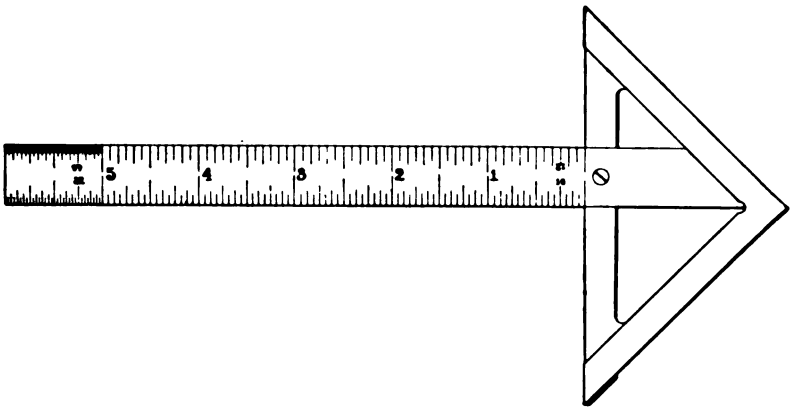


Fig. 12.

The most common tool for *linear measurements*, and one which hardly requires description, is the so called carpenter's or two-

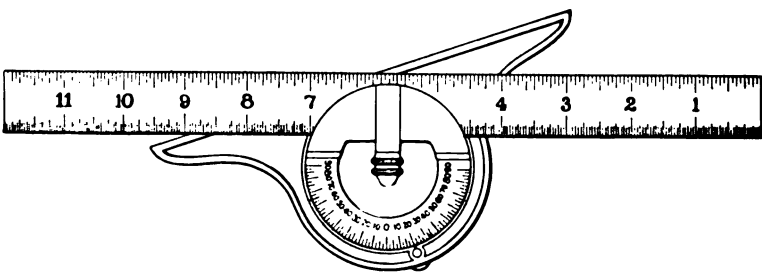


Fig. 13.

foot rule. This is very convenient for the machinist in making measurements which are not required to be very accurate. For

work of greater refinement, the **standard steel scale** (Fig. 15) is used. This is in reality a divided or graduated straight edge and, as such, forms a part of several tools already described. The most common form of steel scale is flat, varying from one to forty-

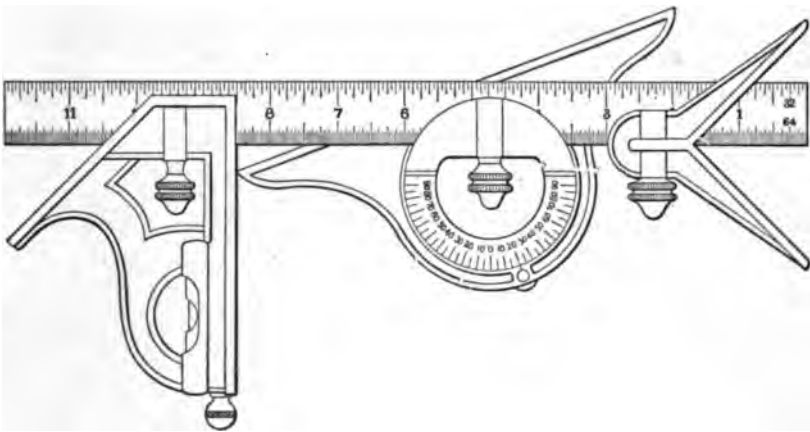


Fig. 14.

eight inches in length, and carefully hardened and ground. The graduations in the better class of scales are cut with a dividing engine, although the lines may be etched on the surface with a fair degree of accuracy. A thin and somewhat narrower form, called a flexible scale, is made in sizes from four to thirty-six inches. What are known as narrow scales are obtainable from

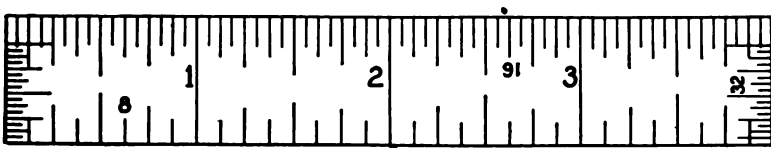


Fig. 15.

four to thirty-six inches, and are of great convenience in certain cases. Besides these shapes, square scales are made in sizes from three to six inches in length, and the triangular form varies in length from three to twelve inches. Steel scales with the English system of graduation can be obtained with the inches divided in eighths, sixteenths, thirty-seconds, sixty-fourths; twelfths,

twenty-fourths; tenths, twentieths, fiftieths, and hundredths. Special scales are made with graduations especially adapted to such uses as gear blank sizing, etc.

The ends of flat rules are sometimes graduated, making what might be called a very short rule with a handle. Flat rules are sometimes graduated with Metric divisions as fine as one millimeter, and from five centimeters to one meter in length.

For transferring and comparing distances, **dividers** are commonly used. They are classified according to the style of joint

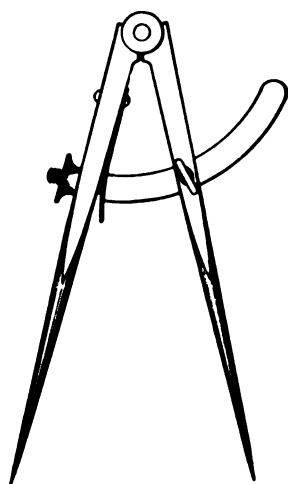


Fig. 16.

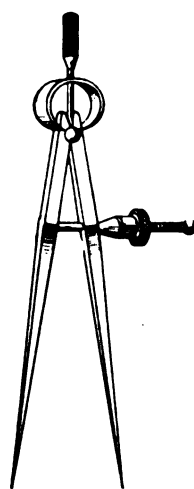


Fig. 17.

and the length of the leg. The most simple joint is the friction, and like all frictional devices, is hard to set accurately. Lock-joint dividers can be moved freely to approximately the right position, the joint locked, and the adjusting screw used for the final setting.

Wing dividers, Fig. 16, are of about the same construction as the lock joint, except that the fastening is made on the wing instead of at the pivot. The best of all forms has a spring adjustment as shown in Fig. 17. In this type, a spring tends to open the dividers, and the legs are closed against the spring by a nut working on a screw which is fastened to one leg and passes

freely through the other. The length of dividers varies from two and one-half to ten inches. The distance to which dividers can be opened is generally about equal to the length of the leg. For distances above ten inches, *trammel points*, diagram, Fig. 18, are convenient. They consist of hardened steel points attached to metal sockets, and can be used on rods of any length. One point may have a spring adjustment, and in that case can be set in the same manner as a pair of wing dividers.

Next in importance to the dividers as an adjustable distance gauge, are the **calipers**. Instead of having straight legs with

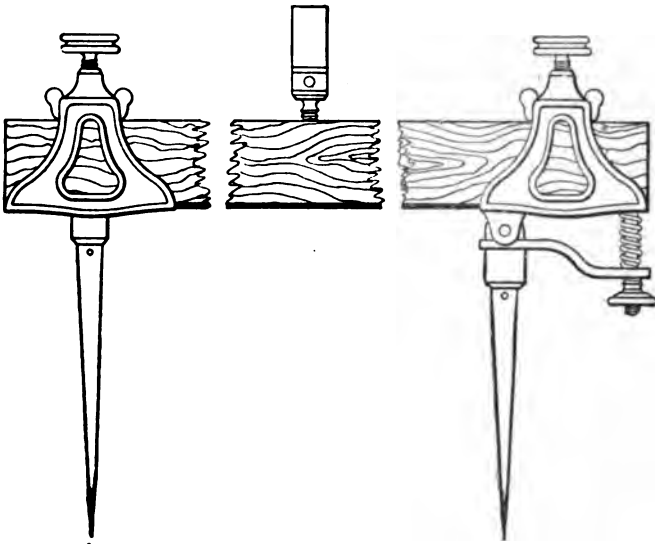


Fig. 18.

sharp points, caliper legs are bent and have blunt points. As distances are to be measured both outside and inside of solid bodies, we have outside and inside calipers. The legs of outside calipers have a large curvature so that the calipers may be passed over cylinders of their greatest capacity.

Inside calipers, Fig. 20, are more like dividers in general appearance, the ends being bent outward slightly and the points rounded. The same styles of joints used in dividers are used in calipers, and the size of calipers is also designated by the distance from the joint to the end of the leg. Spring calipers are made

in sizes from two and one-half to eight inches, while the other styles vary up to twenty-four inches.

As it is sometimes necessary to make measurements behind shoulders and in chambered cavities, where the ordinary calipers could not be removed after setting, it is necessary to have calipers so arranged that they may be set, changed to clear the obstruction, and then reset accurately in the first position. This is accomplished by **transfer calipers**, shown in Fig. 19, in which one leg is temporarily fastened to a stub or false leg. After set-

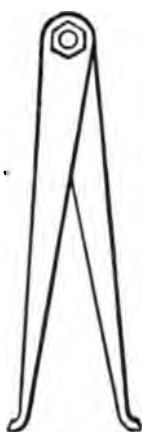


Fig. 26.

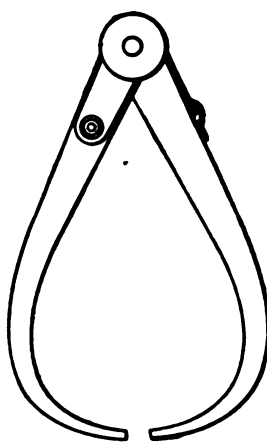


Fig. 19.

ting, this leg may be moved away from the stub, the calipers withdrawn, and the leg again placed in contact with the stub; the points will then be found to occupy the same position as when first set. Small curved legs may be used in place of points or trammels in calipering large objects.

Both dividers and calipers are usually set by means of a scale. In setting dividers, place one point in a graduation of the scale, and move the other until it falls easily into another graduation which gives the required distance. Outside calipers are often set by placing one leg against the end of the scale and moving the other until it is opposite the middle of the graduation giving the required length. As the graduations are not mathematical lines, but have an appreciable width, this last precaution is one of

great importance. Inside calipers are set by placing both the scale and caliper toe against a plane surface as shown in Fig. 21; the other toe is then set the same as the outside caliper.

Caliper legs are comparatively slender, are easily bent, and care must be taken in using them to see that the contact with the object being tested is very light. It is an easy matter to spring calipers of common sizes as much as one-sixteenth of an inch.

The **caliper square** is made by attaching a movable blade to the common square. In the ordinary forms it closely resembles a steel rule with two arms extending from it at right angles, one fixed near the end and the adjustable arm sliding along the scale with a clamping device for adjusting this movable arm. In order that the

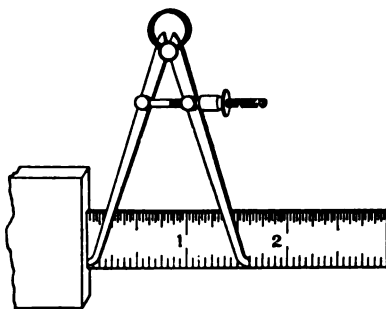


Fig. 21.

movable arm may be set accurately, caliper squares (Fig. 22), as at present constructed, have two clamps for the movable arm. The one carrying the thumb nut is to be first clamped in approximately the right position; the clamp on the movable arm being

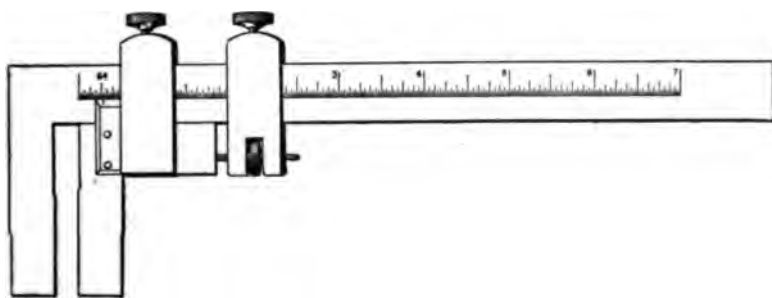


Fig. 22.

secured after the adjustment has been made by the nut. The sizes used vary from three inches up, and are limited only by the length of scales obtainable.

For measurements which are required to be more accurate than can be obtained by the preceding forms of calipering devices, the

micrometer caliper, Fig. 23, is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

It consists, essentially, of a crescent-shaped frame carrying a hardened steel anvil B at one end and a nut of fine pitch at the other; the axis of the nut being at right angles to the face of the anvil. The outside of the nut, A, forms a projection beyond

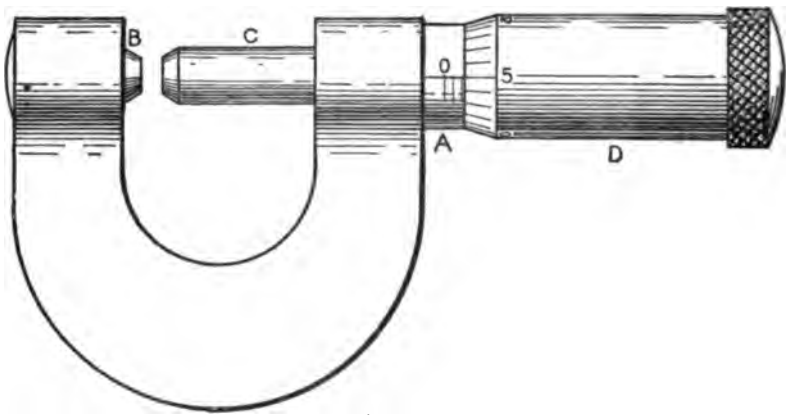


Fig. 23.

the crescent that is called the barrel. The measuring screw consists of a fine-pitched screw to fit the nut, combined with a measuring point C, having a face parallel with that of the anvil. Firmly attached to the outer end of this screw, is a thimble D, fitting closely over the barrel; the edge of this thimble is beveled so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel indicates a movement of the measuring point of one thousandth of an inch. For example: if the pitch of the measuring screw is one hundredth of an inch, there should be ten divisions on the

thimble; if one fiftieth of an inch, twenty divisions; if one fortieth of an inch, twenty-five divisions; if one twenty-fifth of an inch, forty divisions. Measuring screws having a pitch of one fortieth of an inch are commonly used, and every fourth division on the barrel lengthened and numbered to indicate tenths of an inch as shown in Fig. 25.

In using the micrometer caliper, it should not be set at the size required and pushed over the work, but should be screwed down until the measuring point C and anvil B are in contact with the work; the size may then be read from the relation of the thimble to the reference line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble so that undue pressure cannot be exerted.

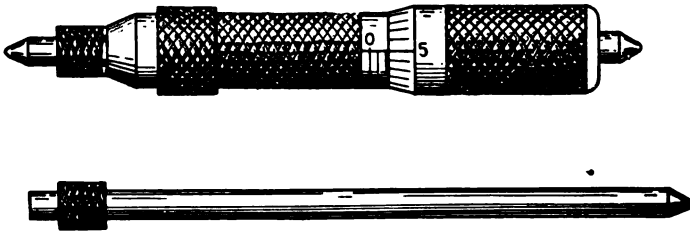


Fig. 24.

The micrometer caliper will not only indicate that the work is too large or too small, but will also show exactly the amount by which it differs from the desired measurement. This is a great improvement over the rigid form of calipers, and enables the workman to judge more accurately the progress of the work. This form of caliper is rapidly coming into favor in spite of its cost, and for this reason it has been described more at length than the common forms previously considered.

The range of motion of the measuring screw is usually limited to one inch. Various devices give the micrometer caliper a larger range of action. Micrometer calipers may now be purchased in combinations or sets giving a range from zero to twelve inches.

The application of the micrometer principle to inside meas-

urements is not in general use, but is easy to arrange, and makes a very simple instrument, as shown in Fig. 24. It consists of an ordinary micrometer head, except that the outer end of the thimble carries a contact point, attached to a measuring rod which may be of any length. Two inches is about the shortest distance that can be measured with this device, but there is hardly any limit in length, as the rigidity of the rod is easily provided for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement, and thus limits this form to about 12 inches, as above stated. The contact points in the outside type are parallel plane surfaces, and in the inside form are rounded points of small radius. Outside micrometers are pro-

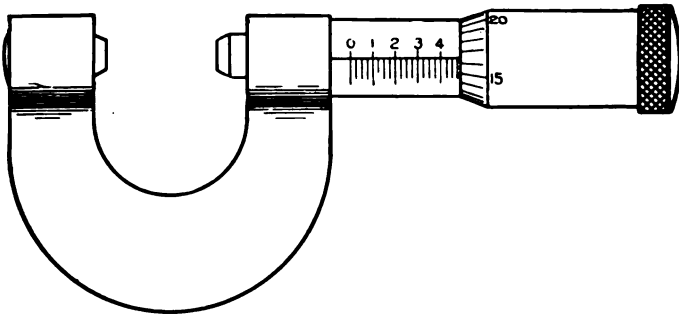
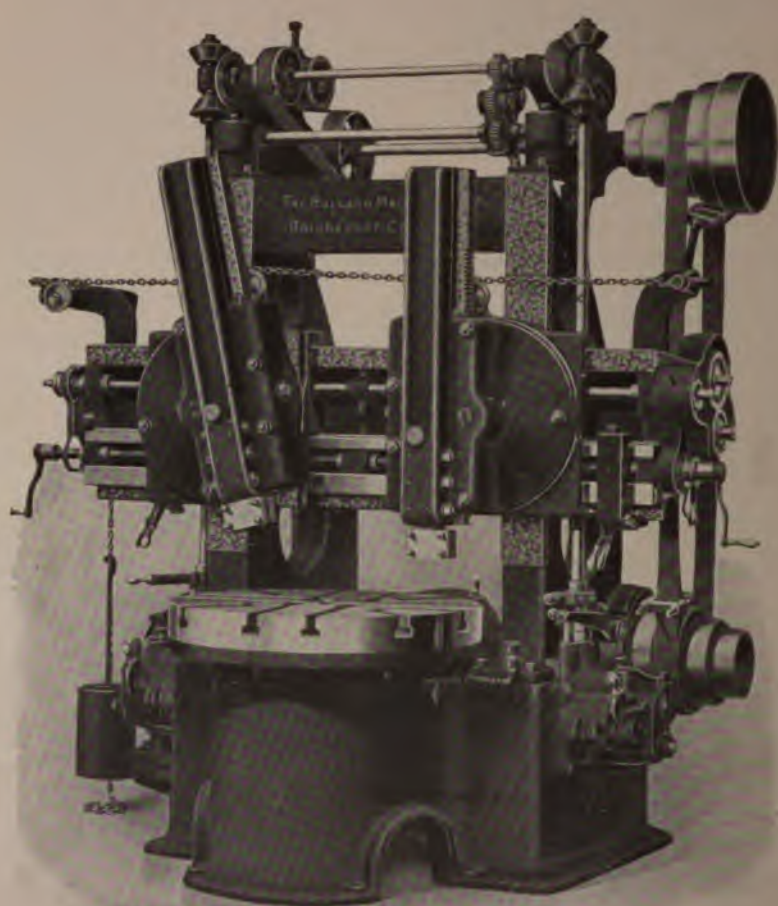


Fig. 25.

vided with contact points of varying forms for measuring paper, threads, walls of tubes, etc. The shapes for these purposes will not be shown, but may easily be imagined.

Reading the Micrometer. As stated above, the micrometer screw has 40 threads per inch and the thimble has 25 divisions on its circumference. The barrel is divided to correspond to the pitch of the screw with each fourth division numbered. In reading the indicated measurement, first note the highest number visible on the barrel, and call it hundreds of thousands or tenths. (In Fig. 25 it is 400 thousandths or .400.) Then read the short divisions on the barrel, calling the first division 25 thousandths (.025), the second 50 thousandths (.050), and the third 75 thousandths (.075). In this figure the third division is the last one visible. Now read the number indicated on the thimble; that is,





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the number that has passed the line running lengthwise. In the figure it is 16; or $16\frac{1}{2}$ if the reading is to be finer than thousandths. Add this reading to the readings of the short divisions, thus: $75 + 16\frac{1}{2} = 91\frac{1}{2}$; this is $.091\frac{1}{2}$. Adding the $.400$ to this we get $.491\frac{1}{2}$. This means that the distance from the anvil to the measuring-point is $\frac{491\frac{1}{2}}{1000}$ of an inch, or $.4915$ inch. If the micrometer caliper is a good one, we may be sure the distance is between $.491$ inch and $.492$ inch.

The Vernier. As has already been stated, the finest graduation that can be easily read on a steel rule by the naked eye, even after much practice, is one-hundredth of an inch. With the growing refinement in measurements, it was found necessary to obtain readings finer than this, and a method of subdivision, known from the name of the inventor, as the "Vernier," was adopted. The principle will first be explained. (See Fig. 26.)

Let two rules be so graduated that the true scale has each inch divided into ten equal parts, and the Vernier scale has ten divisions occupying the same space as nine of the divisions of the scale. It is evident that one of the divisions on the Vernier is equal to $\frac{9}{10}$ of one of those on the scale. Now, if the Vernier be moved to the right so that the graduations marked

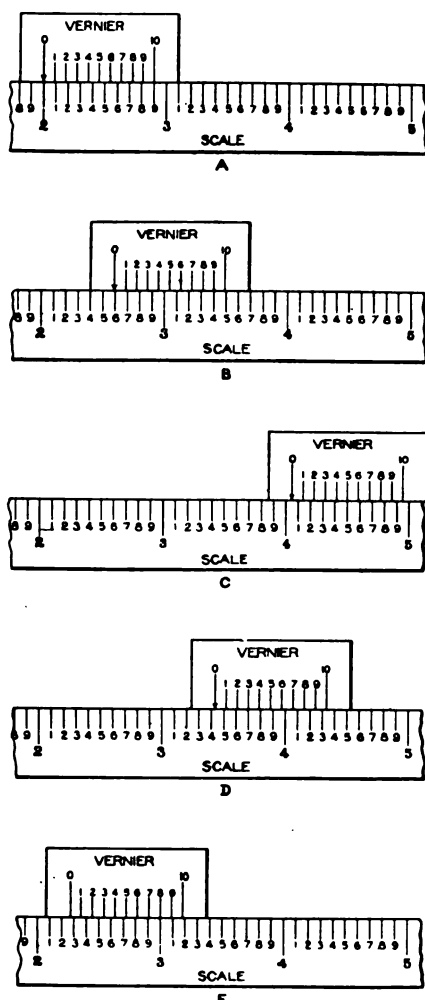


Fig. 26.

1 shall coincide, the Vernier will have moved one tenth of a division on the scale, or one hundredth of an inch; when graduations numbered 5 coincide, the Vernier will have moved five hundredths of an inch; when lines marked 0 and 10 coincide, the Vernier will have moved nine hundredths of an inch; and when 10 on the Vernier comes opposite 10 on the scale, the Vernier will have moved ten hundredths of an inch, or the whole of one division on the scale. By this means the scale, although graduated only to tenths of an inch, may be accurately set at points whose positions are expressed in hundredths of an inch.

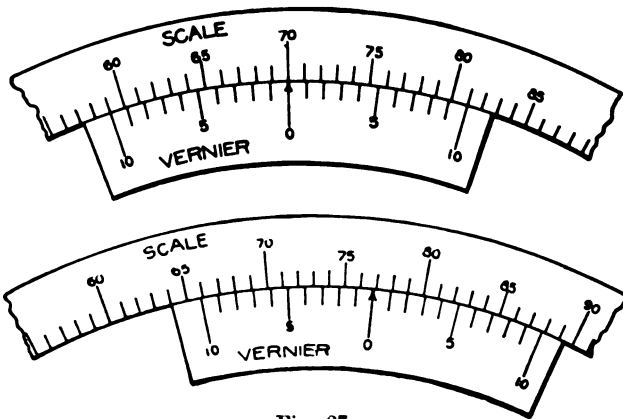


Fig. 27.

Let us consider Fig. 26. At A the Vernier is shown with the 0 in line with 2 on the scale; hence the reading is 2.000.

In B, the 0 of the Vernier has moved to the right beyond the division marked 5. The line 9 on the Vernier is in line with a line on the scale; hence the reading is 2.59.

In C, the zero of the Vernier has moved to the right still farther. The reading is evidently 4.05.

In D, the reading is 3.43.

In E, the reading is 2.28.

While arcs of small radius can be easily graduated into degrees, it is not possible to subdivide the degree without making the divisions confusing. By aid of the Vernier placed just above the true scale representing degrees, readings can be made with accuracy to one-tenth of a degree, or six minutes. The

divisions of such a Vernier scale are shown in Fig. 27, and are also shown when set to read $76^{\circ} 48'$.

The most common application of the Vernier to linear measurements is found in the Vernier caliper square. The one shown

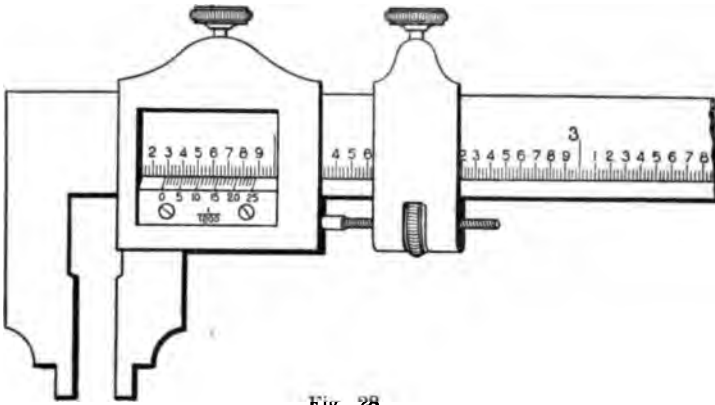


Fig. 28.

in Fig. 28 reads to one-thousandth of an inch. Each inch of the true scale, or beam of the instrument, is divided into 40 parts (every fourth graduation being emphasized), while the Vernier,

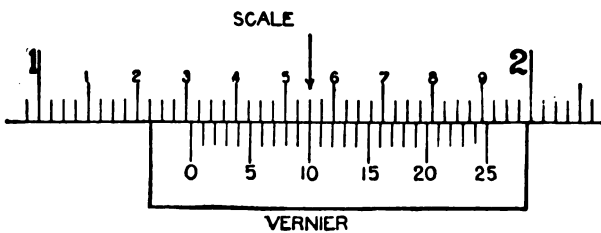


Fig. 28a.

or sliding-scale, has 25 divisions, occupying the same space as 24 divisions on the true scale. By the reasoning used in connection with Fig. 26 the difference in length of one division on the Vernier, as compared with one of those on the true scale, is equal to one twenty-fifth of one fortieth or one thousandth of an inch. The caliper square shown in Fig. 28 is set at .279 inch. The scale is also shown enlarged in which the reading is 1.31 inch.

By the use of the Vernier in connection with the micrometer caliper, readings are easily made to one ten-thousandth of an inch.

As shown in Fig. 29, lines are drawn on the barrel parallel to the reference line, making ten equal divisions occupying the same space as nine divisions on the thimble. Referring to Fig. 30, it will be seen that each division on the thimble may be accurately divided into ten parts, each indicating a difference in the position

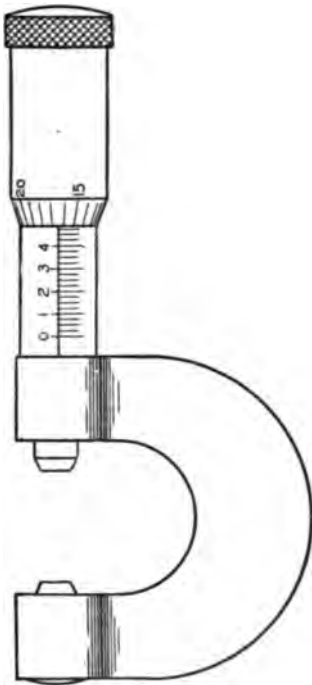


Fig. 25.

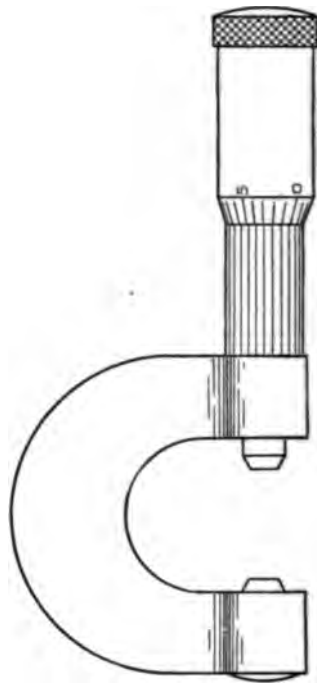


Fig. 29.

of the measuring point of one ten-thousandth of an inch. Rapid reading of the Vernier in any form can only be acquired by practice, but the following directions may be found helpful:

In Reading the Vernier, we must bear in mind the fact that each division on the Vernier is $\frac{9}{10}$ of one division on the scale, and that if line No. 1 on the Vernier is in line with any division of the scale the zero of the Vernier is $\frac{1}{10}$ of one division away from the graduation below it; if line No. 2 is in line, the zero is $\frac{2}{10}$ away from the graduation; if line No. 6 is in line, the zero is $\frac{6}{10}$ away.

Suppose the Vernier is in position on the scale and graduated

as shown in Fig. 30. First read the highest division on the scale to the left of the zero on the Vernier. (69 is the division in the figure.) Then follow along the scale (to the right) until two graduations are found that are in line, as at 6 on the Vernier and 75 on the scale. Now, since one division on the Vernier means that the zero is $\frac{1}{10}$ of a division of the scale away, six divisions of the Vernier means that the zero is $\frac{6}{10}$ away; hence the zero of the Vernier is $\frac{6}{10}$ beyond the 69, and the reading is 69 and $\frac{6}{10}$ or 69.6.

Arcs of circles, such as are on surveyor's instruments, may be graduated to read to half degrees if the diameter is about 8 inches. Now, if we put on the circle a Vernier graduated so that we have 30 divisions equal to 29 divisions of the scale (arc), we can read 30ths of half degrees or *minutes*.

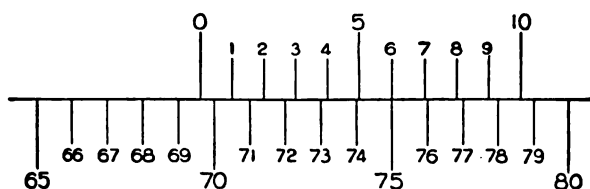


Fig. 30.

Vernier Micrometer. To get very accurate readings, a Vernier scale is placed on the barrel of the micrometer caliper. Let Fig. 29 represent the back side of the micrometer caliper shown in Fig. 25. The reading already obtained was .491 inch. Now turn the caliper over (Fig. 29), and, commencing at the right, count the graduations until one is reached that coincides or is in line with a graduation on the thimble. In doing this, call the first division zero, the second 1, the third 2, etc. The number of the division on the Vernier that is in line with the division on the thimble indicates the ten-thousandths above the regular micrometer reading. From Fig. 29 we see that the 5th line is the graduation which is in line with the division on the thimble which should be called 4, as explained above. Then the reading is .4914 instead of .4915, as we read it from the other side (the plain micrometer). With a good micrometer, we can be sure that the distance between the anvil and the point is more than .4913 and less than .4915.

The Retrograde Vernier. In addition to the direct Vernier, there is another form called the retrograde Vernier, which has 10 divisions on the Vernier and 11 on the scale. In this case the graduations on the Vernier must be reversed, as shown in Fig. 31.

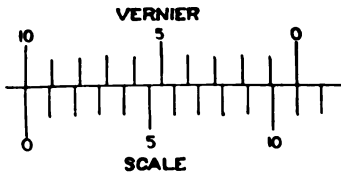
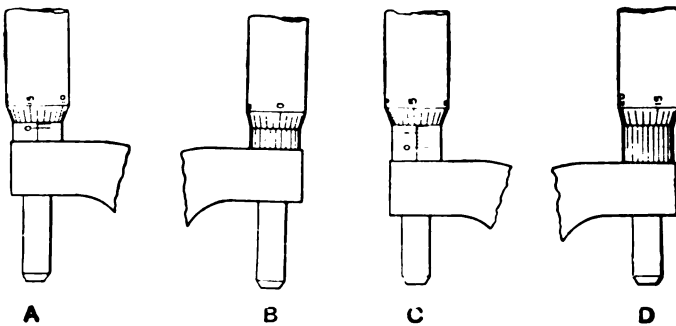


Fig. 31.

Calipers reading to ten-thousandths should not be commonly used when fine measurements are not required, because in an instru-

ment of this class wear is perceptible and important which would be of comparatively little consequence in a caliper that reads only to thousandths.

In using the micrometer caliper for fine measurements, care should be taken in the handling of the instrument. Constant contact with the warmth of the hand will expand it sufficiently to make an error in the reading. The body should be held between the thumb and forefinger of one hand and the thimble turned with the other. It should be laid aside as soon as a reading has been made. It should never be laid upon a piece of cold iron, because the contraction due to chilling is likely to cause an error in the opposite direction from that which would be caused by the heat of the hand.



EXAMPLES FOR PRACTICE.

1. A micrometer caliper shows a reading of .463 ; how many times must the thimble be turned to produce a reading of .587 ? Assume 40 threads per inch.

Ans. $4\frac{3}{4}$ times.

2. What are the readings of the Vernier micrometer calipers shown in Figs. A and B? Ans. .039.

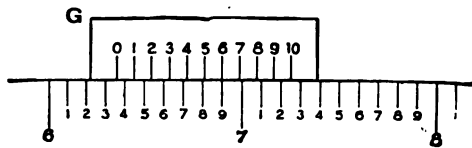
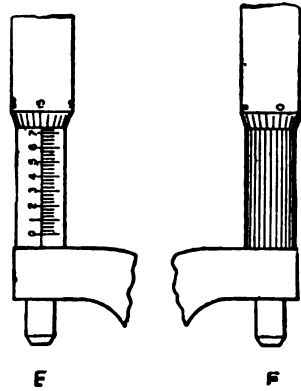
3. State the readings of the micrometer calipers shown in Figs. C and D. Ans. .1546.

4. Give the readings of the Vernier micrometer calipers shown in Figs. E and F. Ans. .7398.

5. Sketch the front and back of a Vernier micrometer caliper when the reading is .6827.

6. What is the reading of the Vernier and scale when in position G?

Ans. 6.36.



Fixed Gauges. While the adjustable gauges that have just been described are available for a large range of work, gauges of one dimension, or fixed gauges, are used to a considerable extent, especially in shops where work of a duplicate character is produced in large quantities. These may be used as standards to which adjustable gauges may be set, or used directly in connection with the work in the same manner as an adjustable gauge. The form of such gauges for comparisons of length is a steel rod with the ends carefully ground so that the distance required may be quickly and accurately determined. In one form the ends are parallel plane surfaces, and in another the ends are sections of a sphere of the same diameter as the length of the rod. Both these forms are illustrated in Fig. 32. Another form of gauge for the same purpose consists of hardened and ground steel disks, Fig. 33, to which calipers and similar tools may be set, and which may be used also to test the size of holes by direct application. For the latter purpose handles are provided by which the disks can be conveniently manipulated.

Plug and ring gauges, as shown in Fig. 34, furnish accurate and convenient standards for the production of duplicate parts of machines. The same result is attained by the caliper gauge shown

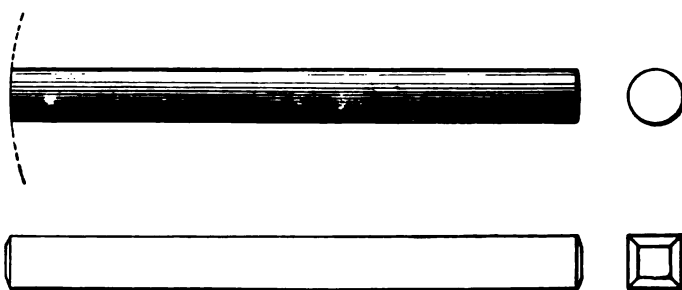


Fig. 32.

in Fig. 35, which combines the two gauges in one piece. In this form the external gauge has parallel plane surfaces and the internal gauge is a section of a cylinder. In sizes above three

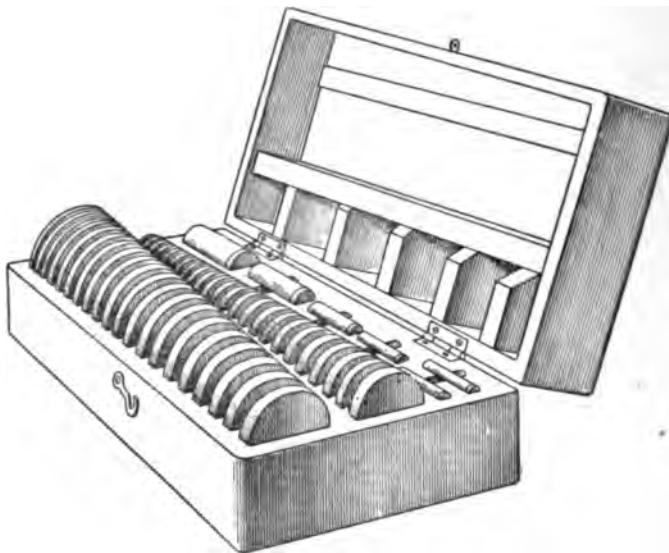


Fig. 33

inches, the caliper gauge is usually made in two parts, also shown in Fig. 35, making the tool easier to handle.

As is indicated by the cost of these gauges, the exact duplication of such exact sizes in quantities would mean a cost that

would be prohibitive in machine construction. The limit of error in the standard gauges just described is never over one ten-thousandth of an inch at a standard temperature, which is usually taken as 70° F. Ordinary machine parts do not require such accuracy,

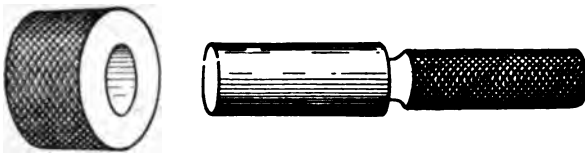


Fig. 34.

and it is usual to allow a limit of error which is in accordance with the class of work being produced.

For testing sizes and dimensions, both at the machine and in the inspection department, combination gauges, known as **limit gauges**, are employed. These are made both for external and

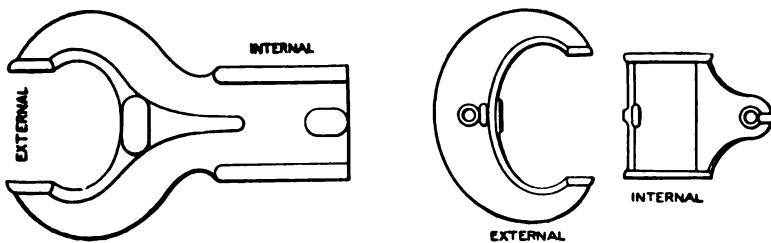


Fig. 35.

internal measurements. The external gauge shown in Fig. 36 is for testing pieces supposed to be .25 inch in diameter. As indicated by the figures on the gauge, the piece is allowed a variation of .0005 inch over, and .001 inch under the nominal size. The words "go on," and "not go on," stamped near the ends, indicate clearly how the gauge is used. This gauge is more conveniently arranged as shown in Fig. 37, in which the work must enter the first parallel opening, but must not pass through the second. In this form, one motion tests the piece for variation above and below the standard. Fig. 38 shows a limit gauge for holes, the end marked "go in" being required to pass into the hole, while the

other end marked "not go in," must not enter. An arrangement of the internal limit gauge similar to the external gauge of Fig. 37 is shown in Fig. 39, and has the same advantages.

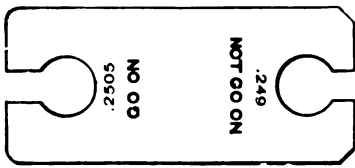


Fig. 36.

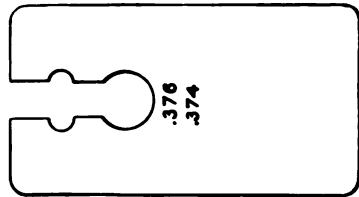


Fig. 37.

In some classes of work, no variation is allowed over the standard, and in others, no variation is allowed under the nominal size. The amount of variation allowed in any case is governed by the class of work and the intended use of the piece. As

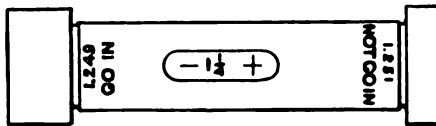


Fig. 38.

these allowances are not uniform, such gauges are made only to order.

For many years gauges of an entirely different character have been used in the measurement of wire, small rods, and sheet metal. The sizes have been designated, not by the diameter or any definite unit, but by a number or letter in a purely arbitrary manner. Even in the same gauge, the sizes do not advance in any regular order. The matter is still further complicated by the fact that in one gauge large numbers indicate large sizes, while in another, the smaller numbers mark the large diameters. Another source of annoyance lies in the fact that such gauges are cheaply made and cannot be relied upon to be duplicates of one another. These gauges were the natural result of the recognition by large manufacturers of the necessity of standards by which to grade their products. Hence we have such gauges as the Brown and Sharpe, Birmingham or Stubs, Washburn and Moen,

United States standard, Morse Twist Drill Co., and many others. As a step in the right direction, a decimal gauge has recently been adopted, in which the sizes are indicated by numbers which represent the diameters in thousandths of an inch. Most of these

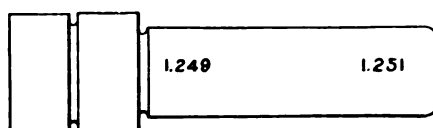


Fig. 39.

gauges had their origin in days when refined measurements were not common, but since the use of the micrometer caliper has become almost universal, there seems to be no good reason why all sizes should not be expressed in thousandths of an inch, thus

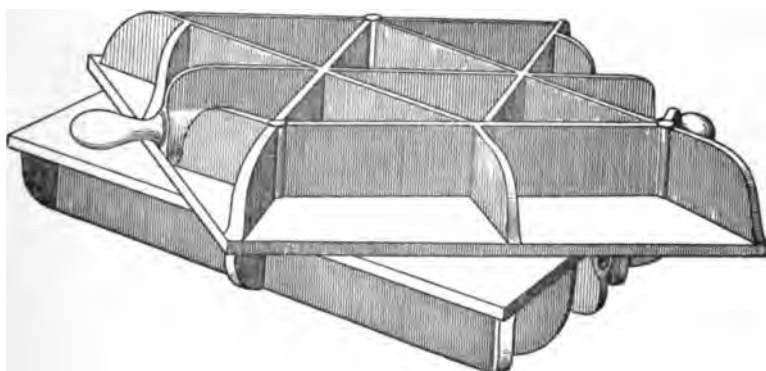


Fig. 40.

avoiding all the troubles incident to the use of the arbitrary gauges.

For the production of accurate plane surfaces the use of the straight edge is not sufficient. Such surfaces should be compared with standard surfaces called surface plates, Fig. 40. A surface plate is a cast-iron plate strongly ribbed on the back to prevent distortion, and supported on three points to insure a uniform base. The production and use will be described under the head of "Scraping." They may be had in sizes varying from 3 inches by 4 inches to 36 inches by 72 inches.

The machinist's **bench** at which hand work is ordinarily performed should be of substantial character, about two feet ten inches from the floor and two feet six inches wide (see Fig. 41). For the sake of economy it is usual to have a two and one-half or three

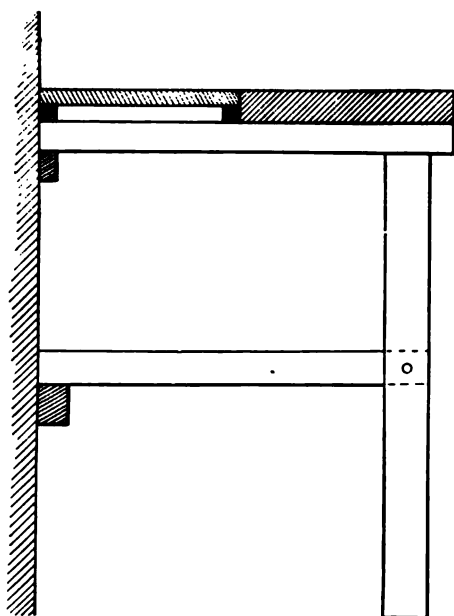


Fig. 41.

inch plank at the front to which the vises are fastened and on which all the heavy work is done, while the rear of the bench is made from one-inch stuff. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a *vise*. They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable

jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 42, shows these parts clearly and also a device, present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out in the nut.

In the machinist's vise, both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid the marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 42, although a swivel base such as is shown in Fig. 43 is preferable. The vise shown in Fig. 43 has a swivel jaw also which enables it to hold tapered work securely. This swivel jaw is provided with a locking-pin which fixes the jaws in a parallel position. The height of the

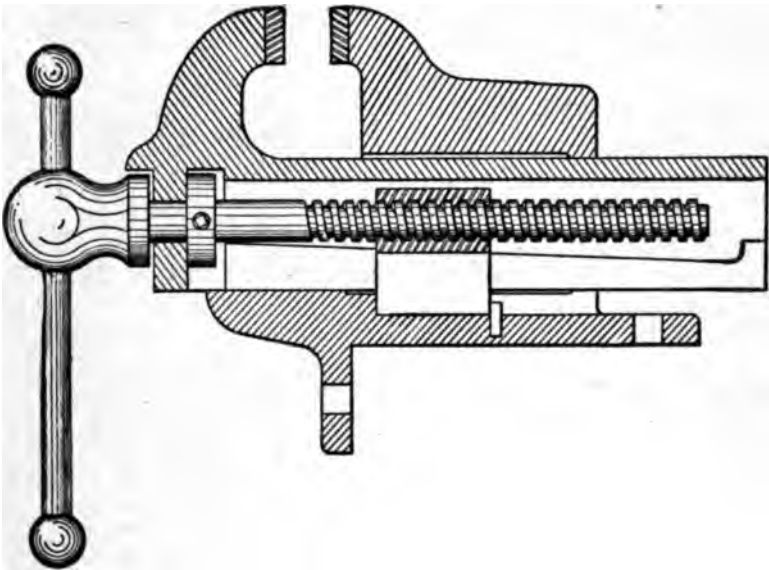


Fig. 42.

vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaws about one and one-half inches below the point of the elbow when standing erect beside the vise.

CUTTING TOOLS.

The simplest form of metal-cutting tool is the chisel. The several types in common use are shown in Fig. 44. The **flat chisel** is used for snagging castings, for chipping surfaces having less width than the edge of the chisel, and for all general chipping operations. It is the form most commonly used, and is often called the cold chisel. Generally it has a cutting edge

about an eighth of an inch wider than the stock from which it is forged. The **cape chisel** is used for cutting key ways, channels, and for the fine straightening of surfaces to avoid chipping with the flat chisel. It resembles the latter, except such a surface, leaving raised portions or "humps" to be removed by the flat chisel. The cutting edge of this chisel is usually one-eighth of an inch narrower than the stock, and the part just in the rear of the cutting edge is made thin enough to avoid binding in the

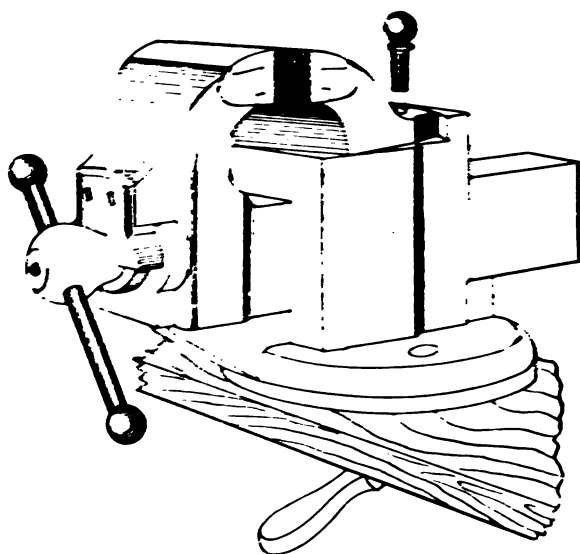


FIG. 43.

slot. As this weakens the chisel, it is made comparatively thick in the plane at right angles to the cutting edge.

The **diamond point** chisel is made by drawing out the end of the stock to about $\frac{1}{16}$ inch square, and grinding the end at an angle with the axis of the chisel, leaving a diamond-shaped point. It is used for drawing holes, making oil grooves, and cutting holes in flat plates.

The **small round-nosed** chisel is cylindrical in section near the cutting end, the edge being ground at an angle of 60° with the axis of the chisel. When used to "draw" the starting of drilled holes to bring them concentric with the drilling circles they are called **center chisels**. This form is also used for

cutting channel, such as oil grooves and similar work. The larger sizes of round-nosed chisels are of the general shape of the cape chisel with one edge rounded, making a convex cutting edge. Large round bottomed channels and all concave surfaces are the proper work of the round-nosed chisel.

All the accompanying forms should be made from a good grade of tool steel, carefully forged, hardened, and tempered to a purple color. The stock generally used is octagonal, and the chisels for heavy work are about eight inches long and three-quarters of an inch in diameter.

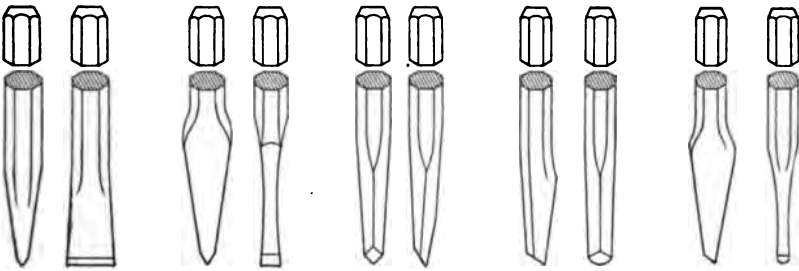


Fig. 44.

The two bevels forming the cutting edge of a chisel should make with each other as small an angle as is possible without leaving the cutting edge weak. If the angle is too small, the chisel will soon become dull, while if large, more force will be required to drive it. The best angle for cutting cast iron, all things considered, is about 70° , while for wrought iron and mild steel a slightly smaller angle, say 60° , will be better. When there are two bevels, they should be alike in width, and form equal angles with the center line of the chisel. Small round-nosed chisels and some slotting chisels are ground one-sided, that is, with but one bevel like a wood chisel. The angle between the surfaces which form the cutting edge should be the same, whether these surfaces are both bevels, or one a bevel and the other the straight side of the chisel. In a one-sided chisel, therefore, the angle that the bevel forms with the center line of the chisel should be twice as large as in one having two bevels.

To cut well, chisels should be sharp, and therefore should

be ground at once when they become dull. This may be done on an emery or carborundum wheel, not finer than No. 60, care being taken to avoid heating, which draws the temper, and spoils the tool.

Chipping is a term applied to the removal of metal with the cold chisel and hammer. The degree of accuracy required varies. The piece is held in a vise, and the method of working is to grasp

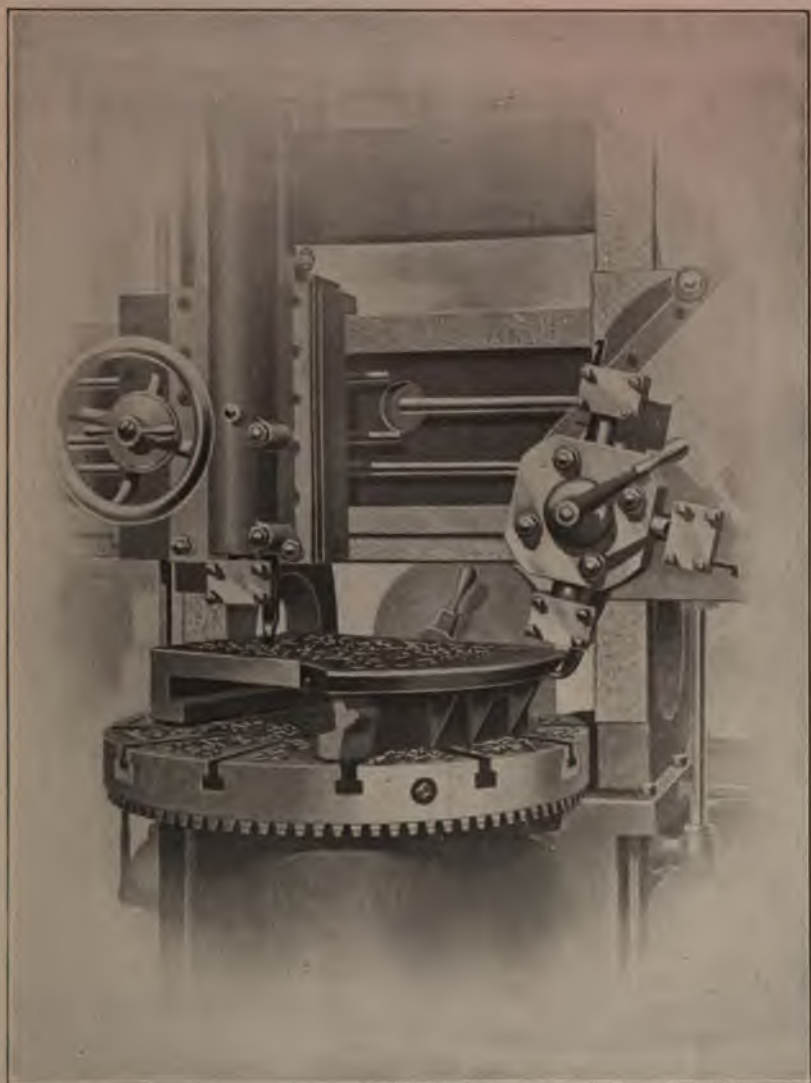


Fig. 45.

the chisel firmly with the left hand, holding the cutting edge to the work, and striking the head of the chisel with the hammer, keeping the eyes on the edge of the chisel to watch the progress of the work (see Fig. 45). The lower side or bevel of the chisel is the guiding surface, and is held at a very slight angle with the finished portion of the work, the cutting edge only touching. Raising or lowering the shank of the chisel increases or decreases the inclination of the guiding bevel, and causes the chisel to take a heavier or lighter cut. If the hand is carried too

low, the chisel will run out before the end of the cut; while if the hand is raised too high, the progress will be slow, owing to the resistance offered by the metal to separation. The depth of the cut taken with a cold chisel should never be more than an eighth of an inch.

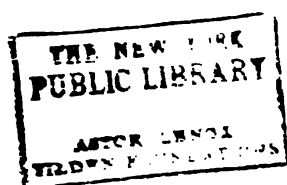
When chipping wrought iron or steel, a piece of waste saturated with oil should be kept on the bench, and the edge of the chisel frequently thrust into it. This lubricates the surfaces in contact and preserves the cutting edge of the chisel. While lines are used as guides in chipping operations, it is never advisable to bring the surfaces too near them with the chisel; sufficient stock must be left so that the surfaces may be finished with a file. This



BORING AND TURNING MILL.

Turning Bevel with Swivel Head.

Bullard Machine Tool Co.



is especially to be observed in chipping key ways with a cape chisel; an ample margin for filing should be left, both on the sides and on the bottom.

The **file** differs from the chisel in having a large number of cutting points instead of one cutting edge, and in being driven



Fig. 46.

directly by the hand instead of by the hammer. As hand power only is used, it is evident that the amount of metal removed at one stroke will be small, and the amount removed by a single tooth will be exceedingly small.

Files are made from cast or crucible steel, and in manufacture pass through the successive processes of forging, annealing, grinding, cutting, hardening, and tempering. They have three distinguishing features, viz., length, kind or name, and cut or

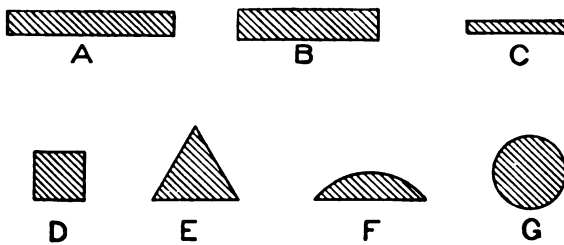


Fig. 47.

coarseness of teeth. Length is measured from the heel A to the point B, Fig. 46; the tang C not being included. These lengths vary from three inches to twenty inches.

There are many kinds manufactured, those in common use being the flat (A), hand (B), warding (C), square (D), three square or triangular (E), half round (F), and round (G), sections of which are shown in Fig. 47.

The cut of files is in two styles, single and double; and each style has several grades of coarseness, viz., coarse, bastard, second-

cut, smooth, and dead smooth. The last two grades are sometimes called fine and superfine. As is shown in Fig. 48, the coarseness of each style varies with the length — the longer the file the coarser the cut.

If the cutting surface of a file were perfectly flat, the number of teeth or cutting points engaged with the work would depend on the width of the file and the width of the piece being filed. To force as many cutting points as would be contained in such a large area deeply enough into the metal to enable each to remove its share of the stock, would be beyond the power of the man

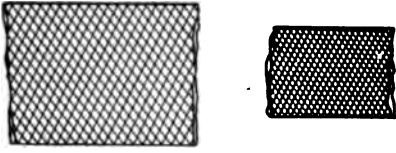


Fig. 48.

pushing the file. To avoid this necessity for great pressure, files are usually “bellied” or made slightly convex in the direction of their length, so that, theoretically, the file and the work are in contact only on a line as long as the width of the file. This enables the file to be forced into the metal sufficiently for the teeth to bite, and thus avoids dulling the teeth, which always occurs when the file is allowed to glide over the work without sufficient cutting.

This convexity of files also serves another purpose. The pressure applied to the file to make it bite bends the file more or less (see Fig. 49), and if the file in its natural state were perfectly flat, when cutting it would be concave; and this would prevent the production of a flat surface. It would cut away at the edges of the work and leave a convex surface. Such files might, however, be used on convex surfaces.

Work for filing is usually held in a vise such as has already been described, and under ordinary circumstances the surface of the work should be about the height of the elbow. For fine work with small files, where close observation is of more importance than pressure on the file, the work should be higher than this, the height increasing with the refinement of the work. On the other hand, for very heavy filing, where great pressure is absolutely necessary, the work should be several inches below the point of the elbow, so that the weight of the body may be used to good

advantage, and also because the workman naturally stoops a little when exerting great pressure on the file.

The handles commonly attached to files are made of wood and are made to fit the hollow of the hand. They are driven onto the tang of the file; a ferrule on the handle preventing it from splitting. Care should be taken to have the axis of the handle parallel with the file. A good way to prepare the handle for the tang is to heat the tang to a dull red, the file proper being kept cool by a piece of wet waste, and the hole in the handle burned

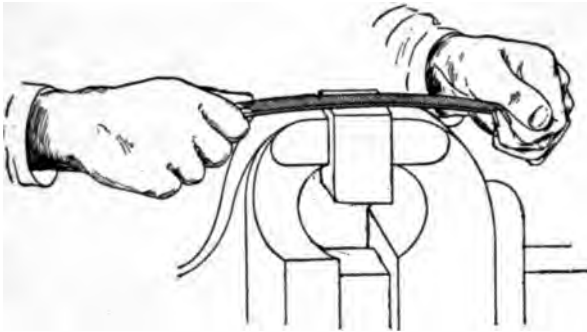


Fig. 49.

out until the tang is almost in the position it is designed to finally occupy. After cooling the tang, very little driving will be required to securely fasten the handle to the file.

When filing surfaces of such size that the handle as ordinarily applied would interfere with the use of the file, the tang may be bent up to an angle so that the handle will clear the surface. Various forms of holders are used for filing under these circumstances; the simplest forms being shown in Fig. 50.

The correct position for filing is about as follows: feet about eight inches apart and at right angles, the left foot being in line with the file; stand back from the vise so that the body may follow the file slightly; grasp the file handle with the right hand, fingers below, thumb on top of the handle; for coarse filing, place the ball of the thumb of the left hand on the point of the file; for fine filing grasp the point of the file with the thumb and forefinger of the left hand. See Fig. 51. When holding the file in one hand, as is often done in light work, the forefinger should be

on top of the file pointing in the direction of its length, as is shown in Fig. 52. This allows free movement of the hand and wrist, pressure being applied principally by the forefinger.

As file teeth or cutting edges point toward the end of the file, it is evident that the file can cut only when moving in a forward direction. On the return stroke, the pressure should be relieved; otherwise the teeth will be dulled when drawn back over the surface.

The kind of metal being worked determines in a great measure the character of the file to be used. Cast iron, especially if the scale has not been previously removed, is particularly hard on a new file, as the glassy character of the scale tends to dull the cutting edges. New files should never be used on such a surface. It is found that on tool steel, and hard materials generally, a sec-

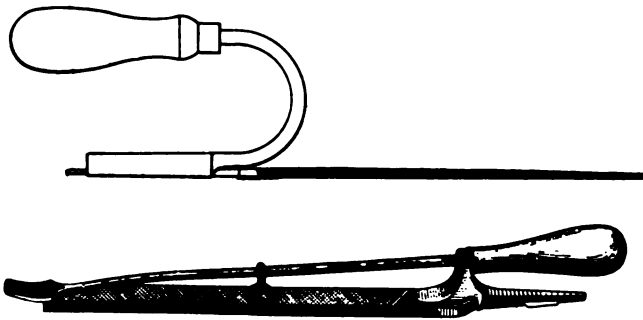


Fig. 50.

ond-cut file is better than the bastard. This is because if pressure enough is exerted to cause the coarse teeth of the bastard to bite into the work, the teeth, being comparatively long, are very likely to be broken off. In the second-cut file, the teeth are shorter and present more cutting points in a given area; thus preventing excessive duty being imposed on a few teeth.

Softer metals, such as brass and bronze, allow the use of the coarser grades.

The particles of metal removed by a file frequently remain in the teeth and diminish their cutting qualities. In the case of hard metals these particles, or "pins," often scratch the work. It is necessary, therefore, that files be frequently cleaned. This may

be done in a measure by striking the edge of the file lightly against the bench or vise, but it is more effectually performed by using a stiff brush or a piece of card clothing (Fig. 53). In the finest grades of files, a thin piece of wood or sheet brass may be drawn across the surface of the file as shown in Fig. 54, and the filings are removed by the points extending into the file teeth.

When filing cast iron, neither the file nor the work should be allowed to become greasy, as this tends to make the file slide without cutting. In filing steel, however, if the file be oiled or filled with chalk, the pinning of the file is prevented in a large degree, and frequent use of the card or brush is not necessary.

What is known as drawfiling is done by grasping the file at each end and moving it sidewise across the work. (See Fig. 55.) The amount of stock removed by this process is usually very small, the object being to lay the file-marks parallel to the length of the work.

Single-cut files are better than double-cut for this purpose, being less likely to scratch the work. The remarks concerning cleaning, oiling, and chalking apply both to cross-filing and draw-filing.

No matter how carefully filing is done, it does not leave a



Fig. 51.

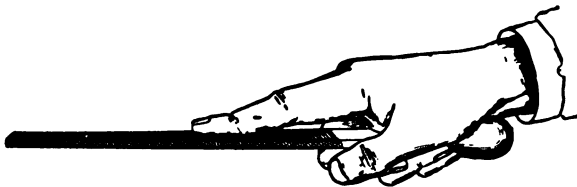


Fig. 52.

surface that is pleasing to the eye; the file-marks are more or less irregular and the whole surface is dull. Exposed parts of machines which are not painted are usually polished. Polishing

does not improve the surface, but simply brightens it and renders it more attractive. As a rule, a polished surface is not a true surface, no care being taken to maintain its truth. In ordinary machine work polishing is usually done by abrasives, such as emery, corundum, and carborundum, while rouge, crocus, rotten-stone, and tripoli are used on fine work, especially on brass and



Fig. 53.

composition. Emery, for example, is crushed and sorted into grades varying from No. 8 to fleur, the number of the grade indicating the number of meshes per inch in the sieve used in sorting. These grades sometimes bear arbitrary designations, No. 1 indicating a coarse grade and No. 0, 00, 000, 0000 showing the finer grades. These powders are sometimes mixed with oil and applied directly to the work by wooden blocks or clamps; but

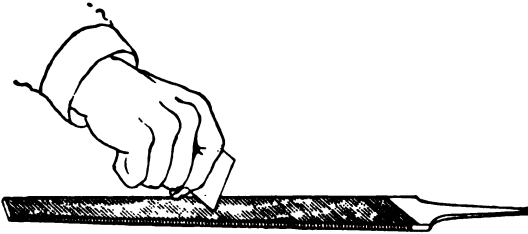


Fig. 54.

the more common method is to use what is known as emery cloth, the grains being glued to a strong cloth backing. The finer grades are used on paper in the same manner.

Emery cloth is used in many ways; it may be wrapped around a file; folded or tacked to a block of wood; glued to wooden sticks about 15 inches x $1\frac{1}{2}$ inches x $\frac{1}{2}$ inch, fastened around rollers for internal curves, or glued to wooden or steel disks and rotated in a lathe or special machine. In all cases the object is to grind down the surface, using a sufficient number of grades of cloth to produce the degree of polish desired. The

marks are laid parallel to each other, making what is known as a "grain." When the process is to be carried to such an extent that no grain is to be visible, the finer polishing agents are used,

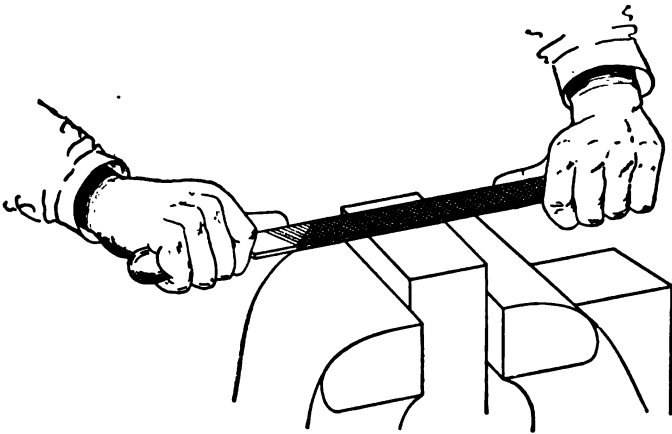


Fig. 55.

usually applied with a cloth wheel or "lap." Old cloth does finer work than new, and oil on the cloth will make a finer cut.

Scraping. When two flat or curved surfaces are to be worked together, and complete contact over the whole or both is desired, they are scraped. Scraping removes less metal than filing, and also enables the workman to confine the removal to limited areas. The scraper should be made from a very close-grained tool steel, and is nearly two feet long exclusive of the



Fig. 56.

handle. The general shape is shown in Fig. 56. The cutting edge is about $\frac{3}{32}$ of an inch thick and $1\frac{1}{2}$ inches wide. It is ground on an emery wheel and grindstone, and carefully oilstoned, leaving the cutting edge as straight as possible. Scrapers are sometimes made from old files, the teeth being ground off and the end drawn out wide and thin. Sometimes the end is bent at right angles to the shank, as shown in Fig. 57. The cutting done by scrapers should be perfectly smooth and free from scratches.

In using the surface plate as a test for the truth of a plane, such as a valve or its seat, the plate is covered with a very thin coating of red lead and then rubbed over the valve or seat. The latter should have previously been finished as smoothly as possible. The spots where the red lead shows contact are scraped off, and



Fig. 57.

the process continued until contact over the entire surface is obtained. During the last part of the operation alcohol should be used instead of red lead, as it leaves clean bright spots to indicate

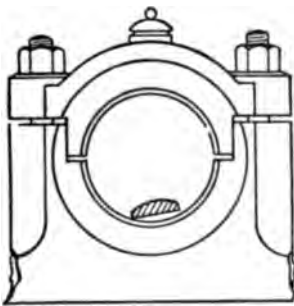


Fig. 58.

where the scraper must be applied. Small pieces of work are rubbed over the surface plate, and in any case care should be taken to distribute the wear uniformly over the plate in order to prolong the truth of the plane. The scraper for concave surfaces, such as boxes, is of the general shape of a half-round file without teeth. In such cases, the shaft to be used takes the place of a surface plate. The method

of holding and using such a scraper is shown in Fig. 58.

Scraping is sometimes done as a matter of finish, and not for the purpose of getting an accurate surface. Therefore, a scraped surface does not always indicate accuracy. Many machine parts are more cheaply finished by scraping than by polishing.

DRILLS.

Drills are of two general classes, the flat and the twist. A flat drill of a common type is shown in Fig. 59. The angle between the two cutting edges should be about 110° . These drills

are usually made from round tool steel drawn out wide and thin, as shown; the undressed end being used for holding. The flat drill is usually made in the shop where it is to be used. Its low first cost is the principal reason for its existence.

Flat drills made from thin flat stock are used in connection with a slotted rest to start and drill holes in the lathe without

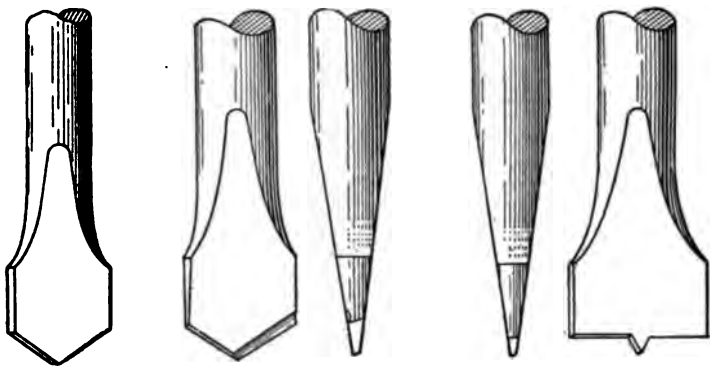


Fig. 59.

previous centering. They are called **chuck-drills**. The end of the shank of the drill is provided with a center hole to receive the dead center of the machine. The drill and rest are shown in Fig. 60.

The simplest form of **twist drill** is cylindrical throughout its entire length, as shown in Fig. 61, and has two spiral flutes which at the end serve to form the cutting lips, and which also

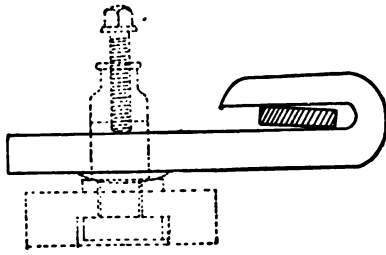


Fig. 60.

serve to carry the chips from the hole. The included angle of the lips is 118° . This form of drill will work more accurately than the flat drill, as the cylindrical portion serves as a guide to keep the cutting lips in their proper position. The edge being somewhat hooking, removes the metal by a cutting instead

of a scraping action as in the flat drill. This form of drill cannot only be fed faster, but can be forced into the work with less power, as it has a tendency, especially noticeable in soft metals, to feed itself into the work. Straight shank twist drills are made from



Fig. 61.

.0135 inch to 2½ inches in diameter; the smaller sizes are sold in sets designated by numbers (1 to 80), letters (A to Z) or fractional sizes ($\frac{1}{16}$ inch to $\frac{1}{8}$ inch).

The *taper-shank twist drill* is shown in Fig. 62. It consists of a body A, which is fluted and does the actual work, and a taper shank B, by which it is held. This taper fits accurately into the spindle or chuck of the drill press. At the end there is a tongue C, which slips into the key way in the spindle or chuck. As this



Fig. 62.

surface is flat, it serves as a bearing by which the drill is driven. This relieves the tapered portion from the stress of driving by frictional resistance alone. For small drills this frictional resistance is sufficient, but for larger sizes it will not do at all. If for any reason the tongue should become broken, no dependence should be placed upon the frictional resistance of the taper shank to drive the drill. The drill will slip and wear the socket, which will become enlarged and make a misfit for other drills.

The **standard taper** for drill shanks may be considered to be what is known as the Morse. This taper is $\frac{5}{8}$ inch to the foot. There is another known as the Brown & Sharpe or Jarno which has a taper of $\frac{6}{10}$ inch to the foot. No attempt should be made to run the drills of one taper in the sockets of the other.

A flat taper key, introduced into the key way, engages the end of the tongue and serves to remove the drill from the spindle.

Drills of cylindrical form are also made with straight flutes as shown in Fig. 63. They are used for drilling soft metals, such as brass, especially when the drill passes entirely through the piece. As it breaks through the metal, a drill with spiral flutes tends to draw itself through rapidly, as if it were a screw work-

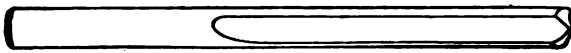


Fig. 63.

ing in a nut. This may break the drill or move the work from position. Straight flutes give the same cutting action as a flat drill and avoid this tendency to draw.

Lubrication of Drills. When drilling tough metals such as steel, wrought and malleable iron, heat is generated by the bending or changing of the form of the metal being removed and by friction caused by the chips moving over the lips of the drill. The heating is similar to the heating of a piece of wire bent quickly back and forth. As there is danger of heating the drill to a temperature that will draw the temper and soften the drill, plenty of lard



Fig. 64.

oil, or a mixture of potash and water, should be used. This is not so much for lubrication as to remove the heat.

Copper is the most difficult to drill of all the common metals on account of its extreme toughness; then, too, copper heats to a higher temperature on account of its low specific heat. Brass does not require the use of oil, and cast iron must always be drilled dry. Particular attention is called to this precaution regarding cast iron.

As the heat is produced at the point of the drill, it is desirable, particularly in the case of deep holes, that the oil be applied directly at the drill point. For this purpose, oil-tube drills, such as is shown in Fig. 64, are used.

The oil is supplied under pressure, and not only removes the heat, but also carries away the chips.

Speed of Drills. The speed at which drills should be rotated depends on the diameter of the drill and the material operated upon. No absolute rule can be given for any one metal or diameter of drill, because of the variation in hardness and tenacity of the material and the condition of the cutting edge of the drill.

The following table of revolutions per minute, given by the Cleveland Twist Drill Co., is based on a peripheral speed of 30 feet a minute for mild steel, 35 feet per minute for iron, and 60 feet per minute for brass.

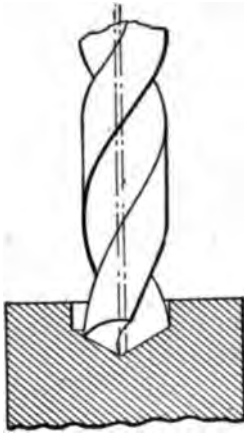


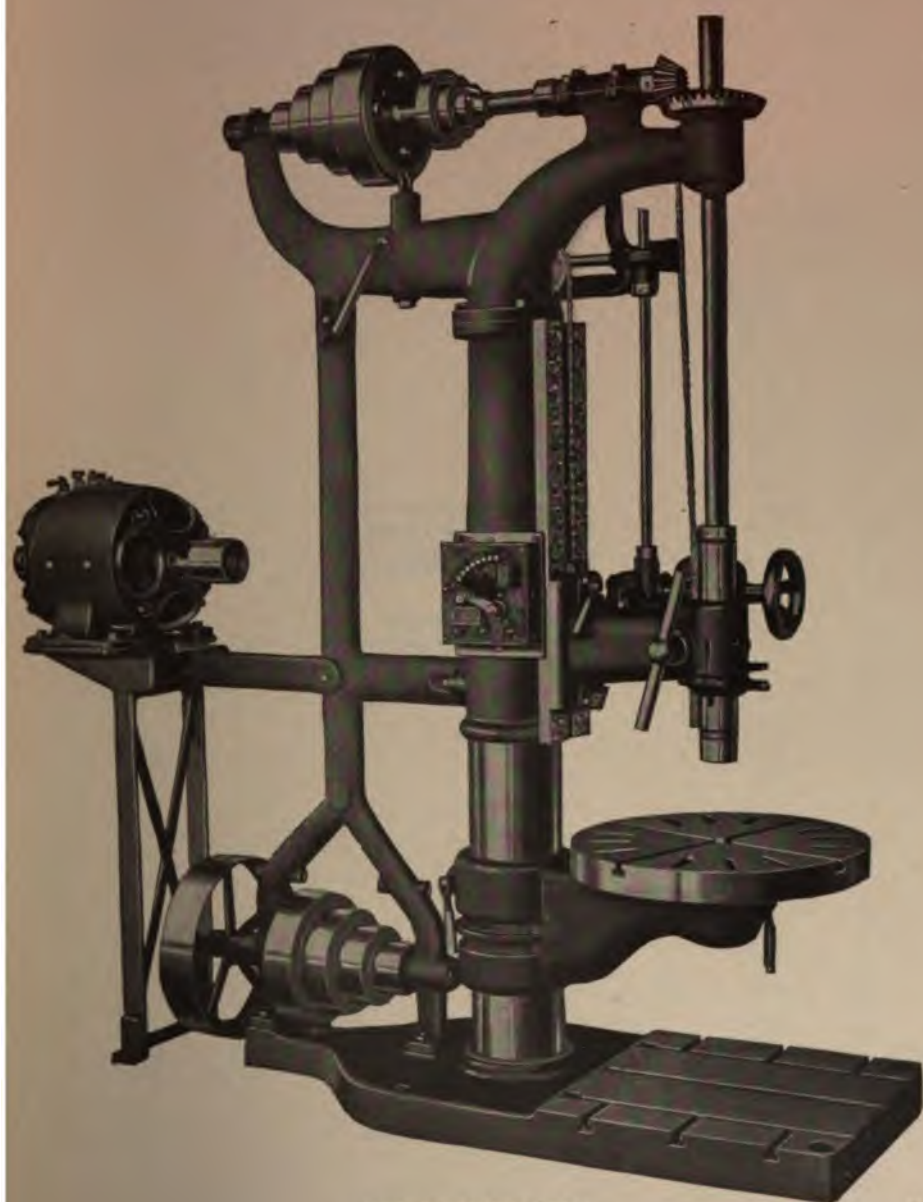
Fig. 65.



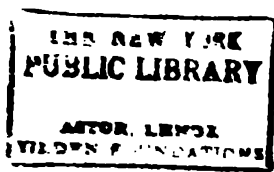
Fig. 66.

The rate of feed also depends on the drill diameter and the material. The above mentioned authority gives, as a maximum, one inch of feed for 95 to 125 revolutions.

Grinding Drills. Great care should be exercised in the grinding of drills. The end of a drill should be symmetrical; that is, the lips should be of the same length, and form the same angle with the axis. If the lips are of unequal length, the hole will be larger than the drill, as is shown in Fig. 65. The point is not in the axis, and the hole will not only be large but also will not be parallel to the drill spindle. If the lips do not form equal angles with the axis, all the cutting will devolve upon the one making the greater angle as shown in Fig. 66. Such a drill will not cut as fast as, and will become dull sooner than, one which is properly ground.



MOTOR-DRIVEN DRILL.



Hand-grinding, especially of twist drills, is neither accurate nor satisfactory; it is much better to do such work on a regular drill grinder built especially for the purpose.

SPEED OF DRILLS.

DIAMETER OF DRILL.	SPEED FOR SOFT STEEL OR WROUGHT IRON.	SPEED FOR CAST IRON.	SPEED FOR BRASS.
$\frac{1}{16}$	1824	2128	3648
$\frac{1}{8}$	912	1064	1824
$\frac{3}{16}$	608	710	1216
$\frac{1}{4}$	456	532	912
$\frac{5}{16}$	365	425	730
$\frac{3}{8}$	304	355	608
$\frac{7}{16}$	260	304	520
$\frac{1}{2}$	228	266	456
$\frac{9}{16}$	203	236	405
$\frac{5}{8}$	182	213	365
$\frac{11}{16}$	166	194	332
$\frac{3}{4}$	152	177	304
$1\frac{1}{8}$	140	164	280
$1\frac{1}{4}$	130	152	260
$1\frac{3}{8}$	122	142	243
1	114	133	228
$1\frac{1}{16}$	108	125	215
$1\frac{1}{8}$	102	118	203
$1\frac{3}{16}$	96	112	192
$1\frac{1}{4}$	91	106	182
$1\frac{5}{16}$	87	101	174
$1\frac{3}{8}$	83	97	165
$1\frac{7}{16}$	80	93	159
$1\frac{1}{2}$	76	89	152
$1\frac{9}{16}$	73	85	145
$1\frac{5}{8}$	70	82	140
$1\frac{11}{16}$	68	79	135
$1\frac{3}{4}$	65	76	130
$1\frac{13}{16}$	63	73	125
$1\frac{7}{8}$	60	71	122
$1\frac{15}{16}$	59	69	118
2	57	67	114

While grinding, care must always be exercised that the cutting edge is not overheated on the stone or emery wheel. If it is overheated, the temper will be drawn and the drill become too

soft to properly do its work. The angle between the front face of the drill and the bottom of the lip may be from 70 to 80 degrees. This will give ample clearance for the bottom of the drill and leave sufficient metal to support the cutting edge.

REAMERS.

It is difficult, if not quite impossible, to drill a hole to an exact nominal diameter. For most work, a variation of a few

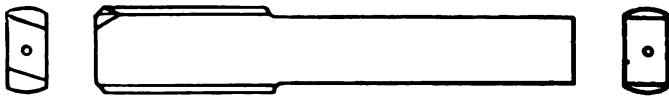


Fig. 67.

hundredths of an inch from the nominal diameter is of no account. Where greater accuracy is required the holes are reamed; that is to say, the hole is first drilled somewhat smaller than it is desired, and is then reamed out to the proper size with a reamer.

Holes drilled with the flat chuck drill mentioned above are usually $\frac{1}{16}$ inch under the finish size. A flat chuck reamer, Fig. 67, is used to enlarge the hole to within about .005 inch of the true size. This reamer is centered on both ends and turned to size.

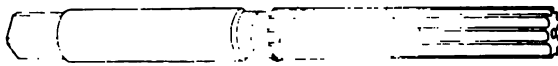
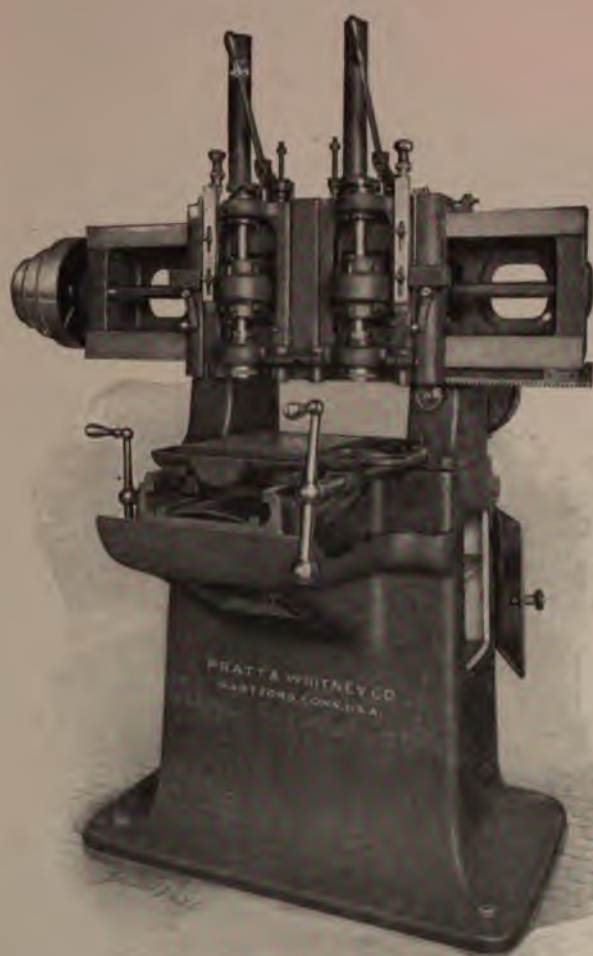


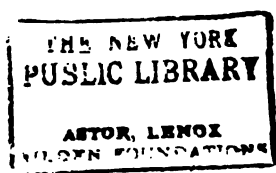
Fig. 68.

The entering rod, which does the cutting, is given a short, sharp taper, while the straight portion serves as a guide to keep the tool in position. By this means the drilled hole is straightened and brought close to size.

To give the hole a smooth surface and correct diameter, a fluted reamer (of which there are various forms) is used. This tool is not intended to remove large amounts of metal, but serves



TWO-SPINDLE PROFILING MACHINE.
Pratt and Whitney Co.



only to increase the size of a hole by a small fraction of an inch up to the diameter required. The hole should not be more than $\frac{1}{8}$ inch smaller than the reamer; this will leave $\frac{1}{16}$ inch on each side for the reamer to cut. If possible, it will be better to drill the hole even nearer than this to the required diameter.

It is evident that if the reamer were to be made of the same diameter throughout its whole length, it would be very difficult

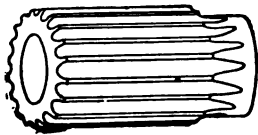


Fig. 69.

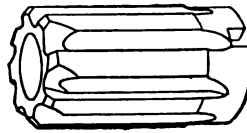


Fig. 70.

to make it enter the hole. In order to facilitate this, it is usually made slightly tapering, for a distance from the entering end, equal to about one diameter.

One form of reamer has a shallow screw thread cut at the entering end. This thread takes hold of the metal and draws down into the work. When using a reamer, it is always well to pass the entire tool through the hole. The leading end is sub-

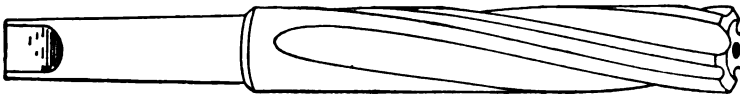


Fig. 71.

jected to the greatest amount of wear because it does the greatest amount of work. If, therefore, only the leading end is put through, the hole will not be of a uniform diameter throughout. Oil should always be used on reamers when they are working in wrought iron or steel.

The hand reamer, Fig. 68, is the typical form, and one which can be used in many cases in place of special forms. Fig. 69 is better adapted for use in the lathe than the hand reamer. This may follow the flat chuck reamer to finally finish a hole.

In reaming cored holes, the cylindrical chuck reamer, sometimes called the roughing reamer, is often used. It is made either rose, Fig. 70, fluted, or with three spiral flutes, Fig. 71, and generally have solid shanks. The last-named style will finish very smooth and close to size when started true by preliminary boring.

A solid reamer cannot be sharpened without reducing its diameter; therefore, it must be used carefully in order to prolong

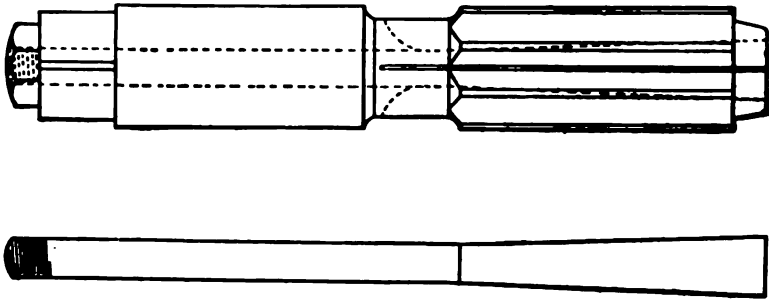


Fig. 72.

its life. Reamers with adjustable blades meet this objection, but cost much more than the solid form. An expanding reamer, Fig. 72, can be slightly enlarged to compensate for grinding, and is then used as a solid reamer. Fig. 73 shows an adjustable reamer with inserted teeth.

Reamers are made for tapered as well as for straight holes. The angle varies with the intended use of the taper; for example,



Fig. 73.

the *locomotive taper* of $\frac{1}{16}$ inch per foot is intended for bolt holes where plates are to be drawn solidly together and the holes completely filled. It is very difficult to remove a bolt from a hole with such a slight taper. When pieces are pinned together, such

as a hub to a shaft, it is intended that they can be separated when desired, so the taper is made steeper, generally $\frac{1}{4}$ inch per foot. This has come to be known as the *pin taper*. Taper holes for holding lathe centers and taper shank twist drills are generally made $\frac{3}{8}$ inch

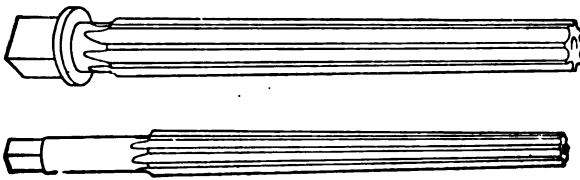


Fig. 74.

per foot (*the Morse taper*). This angle holds the tool firmly, and still it can be easily removed. The three tapers mentioned are recognized as standard, and reamers for them are carried in stock. Of course many other tapers are used by different manufacturers, but they are regarded as special. Fig 74 shows taper reamers.

Taper reamers differ from hand reamers only in the angle and by not requiring the tapered entering end.

Holes to be reamed by taper reamers must be slightly larger than the small end of the reamer; and, if the hole is deep, it is usual to make a stepped hole, shown exaggerated in Fig. 75, by using drills of different diameters.

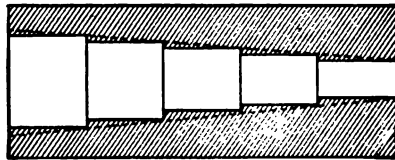


Fig. 75.

When not carefully sharpened, all forms of reamers have a tendency to chatter and produce rough surfaces. To avoid this, the flutes are frequently irregularly spaced; another method is to use spiral flutes, usually left hand.

TAPS.

When internal thread cutting is done, the tool is called a tap. There are many styles of taps; the names in some cases are sug

gested from the shape, but more often from the use. In most machine shops are found the following forms: hand, machine screw, pipe, pulley, stay-bolt, boiler, and tapper; of these the hand and machine screw are the most common. The object of all is to make spiral grooves, called threads, in holes, so that they may receive and hold screws, bolts, studs, etc.

As the size of a tap is the diameter outside the threads, it is evident that the hole drilled for tapping must be smaller than the

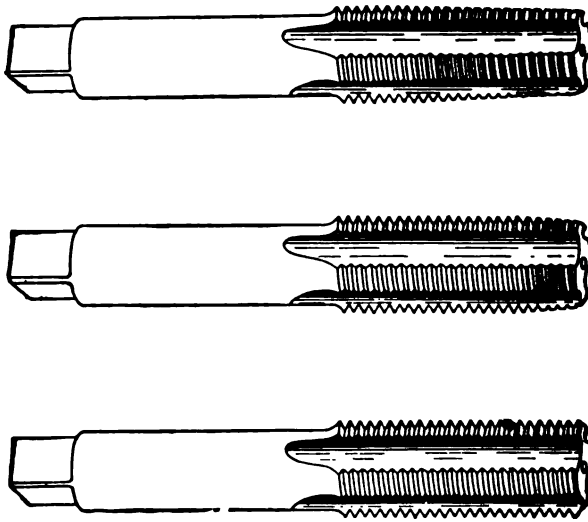


Fig. 76.

tap by nearly, if not quite, twice the depth of the thread. The shape of the thread partly determines the amount to be subtracted from a tap diameter. There are now recognized as standard, five different threads, viz.: sharp or V, Franklin Institute or United States standard, Whitworth, International or metric, and the 29° or Acme. These shapes will be described and compared under Screw Cutting. The following table shows the diameters of the holes that are to be drilled for cutting the various sizes of the threads according to the United States standard and the ordinary V-thread.

Hand taps are most commonly used in shop practice, and a description of the operation will answer for all styles. They are usually sold in sets of three,—taper, plug, and bottoming. See Fig. 76.

The cutting of a thread with a tap is not difficult, but requires care in the manipulation. The tap does not need to be forced into the work, since the thread will draw it forward. The taper-

TABLE OF TAPS AND CORRESPONDING DRILLS.

TAP. DIAMETER IN INCHES.	No. THREADS PER INCH.	U.S. STANDARD DRILL DIAMETER.	V-THREAD DRILL DIAMETER.	TAP. DIAMETER IN INCHES.	No. THREADS PER INCH.	U.S. STANDARD DRILL DIAMETER.	V-THREAD DRILL DIAMETER.
$\frac{1}{4}$	20	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	5	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{5}{16}$	18	$\frac{1}{4}$	$\frac{5}{16}$	2	$4\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{3}{8}$	16	$\frac{9}{32}$	$\frac{3}{8}$	$2\frac{1}{4}$	$4\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{7}{16}$	14	$\frac{1}{2}$	$\frac{1}{2}$	$2\frac{1}{2}$	4	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{1}{2}$	13	$\frac{1}{2}$	$\frac{1}{2}$	$2\frac{3}{4}$	4	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{9}{16}$	12	$\frac{5}{8}$	$\frac{5}{8}$	3	$3\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{5}{8}$	11	$\frac{3}{4}$	$\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{11}{16}$	11	$\frac{7}{8}$	$\frac{7}{8}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{3}{4}$	10	$\frac{7}{8}$	$\frac{7}{8}$	$3\frac{3}{4}$	3	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{13}{16}$	10	$\frac{1}{2}$	$\frac{1}{2}$	4	3	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{7}{8}$	9	$\frac{3}{4}$	$\frac{3}{4}$	$4\frac{1}{4}$	$2\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{15}{16}$	9	$\frac{3}{4}$	$\frac{3}{4}$	$4\frac{1}{2}$	$2\frac{3}{4}$	$\frac{1}{8}$	$\frac{1}{8}$
1	8	$\frac{7}{8}$	$\frac{7}{8}$	$4\frac{3}{4}$	$2\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{1}{8}$	7	$\frac{1}{2}$	$\frac{1}{2}$	5	$2\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{1}{4}$	7	$\frac{1}{2}$	$\frac{1}{2}$	$5\frac{1}{4}$	$2\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{3}{8}$	6	$\frac{1}{2}$	$\frac{1}{2}$	$5\frac{1}{2}$	$2\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{1}{2}$	6	$\frac{1}{2}$	$\frac{1}{2}$	$5\frac{3}{4}$	$2\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{5}{8}$	$5\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	6	$2\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$
$1\frac{3}{4}$	5	$\frac{1}{2}$	$\frac{1}{2}$				

ing of the tap has a two-fold effect. No one thread must do all of the work in the removal of the metal; each succeeding thread removes a small amount until the full thread has entered the hole. The second effect is that, as in the cases of a reamer, the tap is easily entered and started. Care must always be exercised at this point of the work. The taper of the tap allows it to easily enter the hole, and also makes it possible for it to enter at an angle. If

it is started in the latter condition, the thread will not be at right angles to the surface. The degree of care needed in the starting of the tap depends upon the job that is to be done. In the case of tapping a nut, it will usually be quite sufficient to set the tap by the eye. In finer classes of work, however, the tap should be set with a square. Start the tap into the hole, and place a square on the surface beside it in two positions at right angles to each other, and see that the tap stands parallel to the vertical blade.

When holes have been drilled that are to be tapped, a good way of setting the tap is to put a center in the drill spindle. Put the tap into the hole, and bring this center down into the center hole in the head of the tap; this will steady the latter while it is being started.

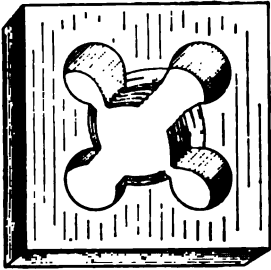


Fig. 77.

In using the tap, it is well to work it back and forth. This allows the chips to work clear of the cutting edges, and the oil to cover them. In case of heavy work, it is possible to drive the tap with the drill spindle, but when thus driving a tap in a machine, the

backing up is impossible.

Sometimes a thread is to be cut down to the bottom of a hole that does not pass entirely through the metal. In this case the bottoming tap is used. This is a tap that is not tapered at the entering end. The method of working is to first cut the thread as far as possible with the plug tap, and then use the bottoming tap, which will then enter easily and can be driven to the bottom.

Machine tapping is best done by using a frictional tap holder; that is, one in which the friction is enough to cut the threads, but which will slip when the tap strikes the bottom of the hole. This will insure the hole being tapped to the bottom, and avoid all danger of breaking the tap. To withdraw the tap, the machine is reversed, usually at a higher speed than used in tapping.

When tapping wrought iron and steel, a plentiful supply of

oil should be used. On brass the use of oil is unnecessary, while cast iron should always be tapped dry.

DIES.

Dies are used for cutting threads on bolts and other similar parts to be placed in holes which have been threaded by taps.

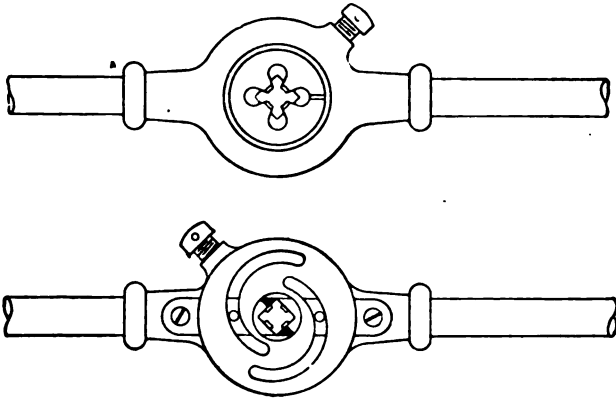


Fig. 78.

The general rules given for the use of taps apply to dies. As the number of threads in a die is much less than on a tap, and because the chips have a much freer exit, it is not as necessary to back up a die as it is a tap.

Dies for small work are usually made solid, as shown in Fig. 77, and often have a slight adjustment for altering the size. They cannot be sharpened, but have an advantage in readily centering on the work. As the full thread is cut at one passage of the die, it takes considerable power to operate solid

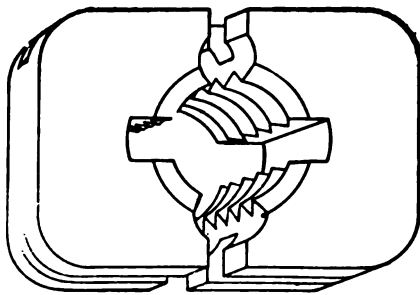


Fig. 79.

dies of large size. For this reason, hand-operated solid dies are seldom used above one-half inch. The holder or die stock shown

in Fig. 78 has a guide to hold the work at right angles to the die, but die stocks are often made without this convenience.

The split form of die, generally known as the jamb-die (shown in Fig. 79), can be easily sharpened, has unlimited adjustment for size, and cuts the thread by easy stages, as it were.

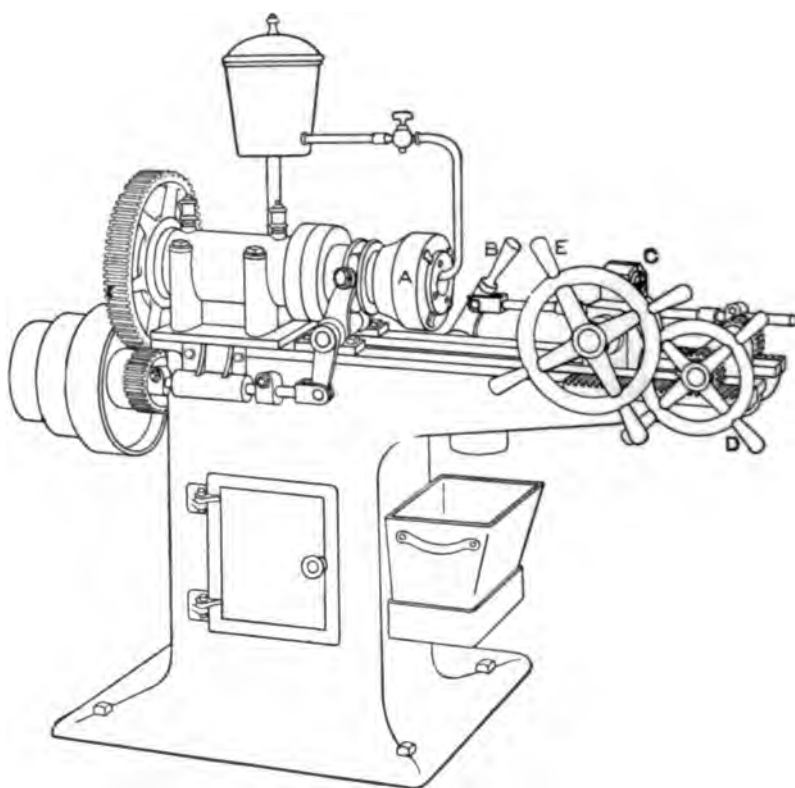


Fig. 81.

It is made in sizes up to two inches, and is for hand operation only. The holder for this form of die is called a screw plate, Fig. 80. These are not furnished with guides for the work.

Cutting Pipe Threads. Another common form of thread cutting is that on wrought-iron pipe. The pipe thread is rounded

slightly at top and bottom, and is made tapering at the rate of three-quarters of an inch per foot. The dies are usually solid, square in form, and the die stocks are provided with a ring,

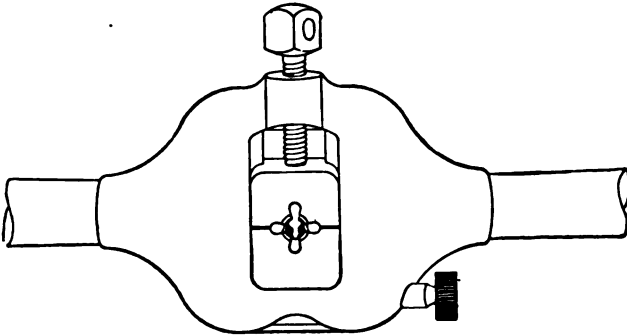


Fig. 80.

which fits over the pipe and serves to hold it square with the die. This avoids the danger of cutting the thread at an angle with the pipe axis.

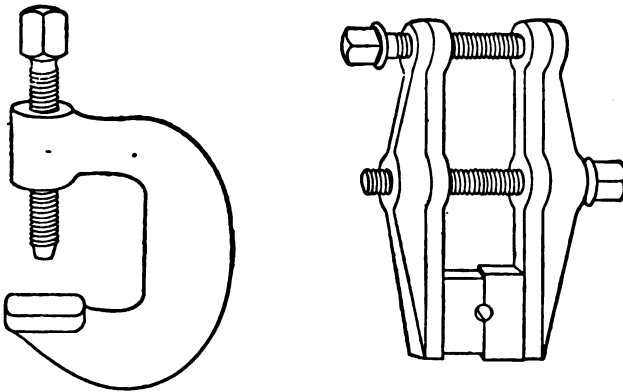


Fig. 82.

Comparatively little thread cutting is done by hand. A large proportion of all such work is performed on bolt-cutters. This is ordinarily the roughest and cheapest class of work, and the run-

ning of the bolt-cutter is usually the first work to which the apprentice is assigned.

Bolt-Cutter. An ordinary type of bolt-cutter is shown in Fig. 81. The dies are held in the head A. Instead of being solid, as in Fig. 77, they are made in sections, and can be opened or closed by the movement of the lever B. A chuck, C, is placed on a traveling head, and this can be moved back and forth by the hand-wheel D. The method of working is very simple. The dies in the head are closed in order to be in the working position. The bolt to be cut is gripped in the chuck by turning the handle E, and forced against the dies by the handle D. As soon as the dies have taken hold, they draw the bolt ahead. When a sufficient length of thread has been cut, the dies are opened and the bolt withdrawn. This avoids the necessity of backing out, as would be required if the dies were solid. While the thread is being cut, the dies are kept flooded with oil.

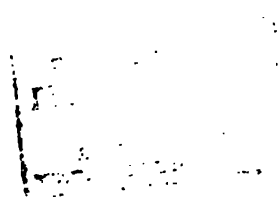
Templets. Where the same piece of work is to be many times repeated, templets are used. This method avoids the necessity of making measurements in the laying out of the work.

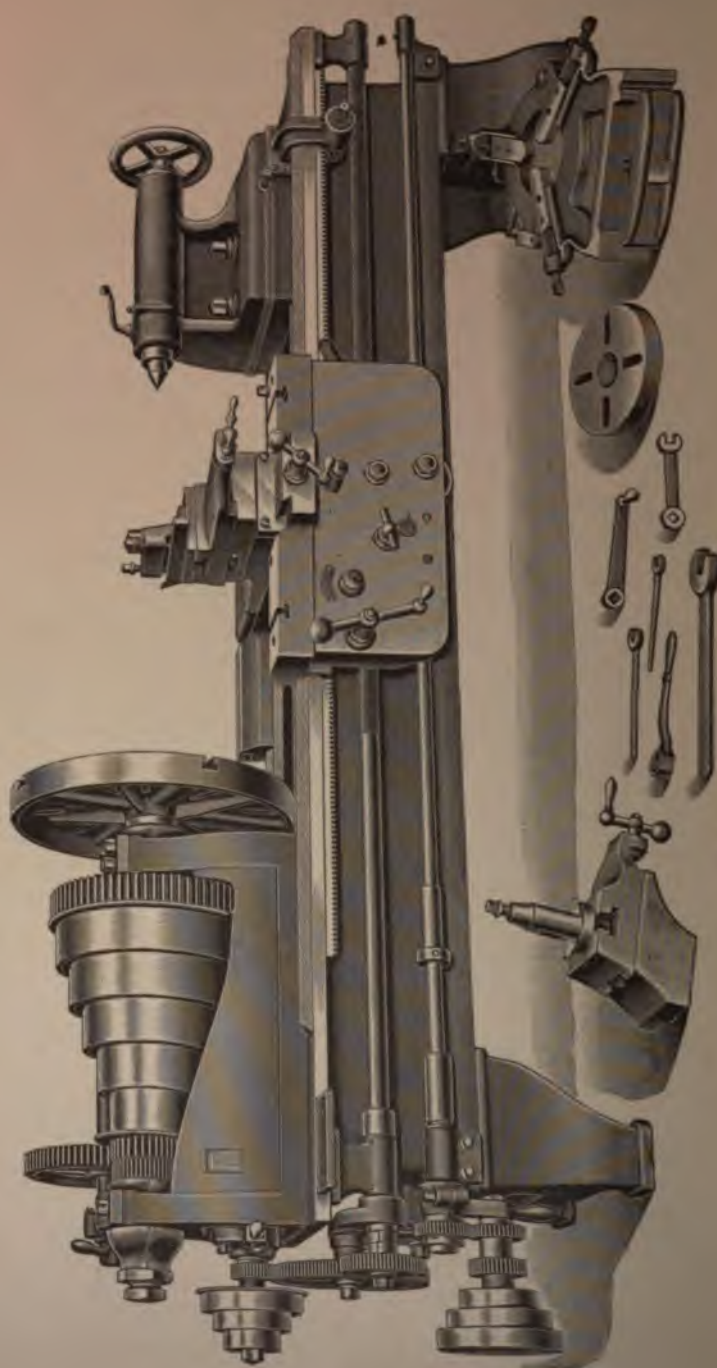
The *marking templet* consists of a piece of the same shape as the finished article. It is usually laid on a flat surface, and held fast by iron clamps as shown in Fig. 82. The outline is then marked on the surface with a scribe, and sometimes emphasized by prick punch marks.

The *filig templet* is of the same character as the one just described, but it is hardened. It is clamped in the vise with the piece to be shaped, and the surface filed down to coincide with the form of the templet.

Where holes are to be drilled in duplicate, a templet known as a *jig* is used. These jigs are made so that they fit over the piece to be drilled, and, when clamped in position, indicate the location of the holes by means of hardened steel bushings set in the templet.

The making of templets and jigs is one of the finest branches of the machinist's work, and is generally classed under the head of tool making. The rapid and economical production of machine parts in quantity depends largely on the tool maker, who must, therefore, be considered the highest type of machinist.





24-INCH SWING ENGINE LATHE.
F. F. Reed Company.

MACHINE SHOP WORK.

PART II.

THE LATHE.

THE lathe is one of the most ancient of tools, and is a development of the potter's wheel. The spindle is horizontal and the work is revolved while the cutting tool is stationary. In its

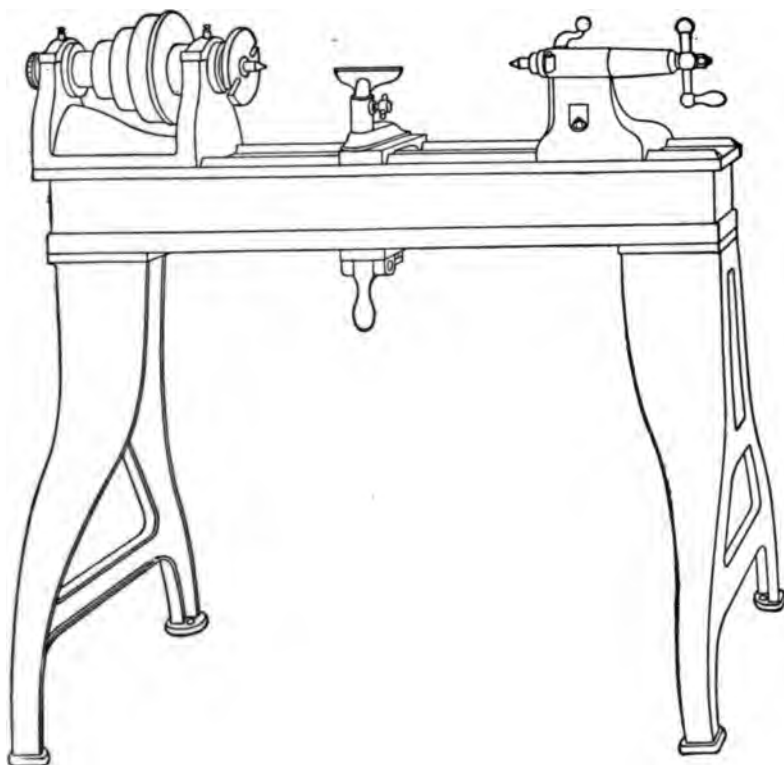
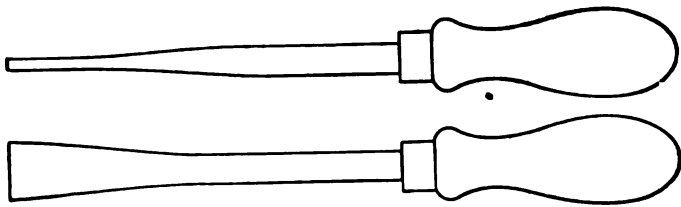


Fig. 83.

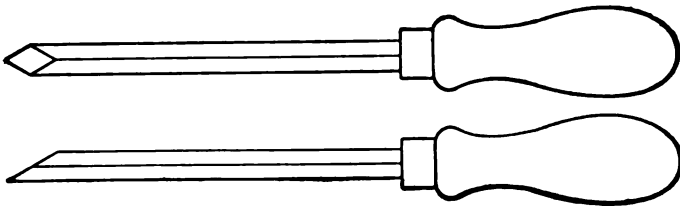
various forms and sizes it is by far the most important tool in the machine shop. It is built in a wide range of sizes from the delicate instrument suitable for the work of the jeweler to the great machine capable of turning engine shafts for the largest ocean

steamships or the rings for the heavy ordnance of battleships and fortifications.

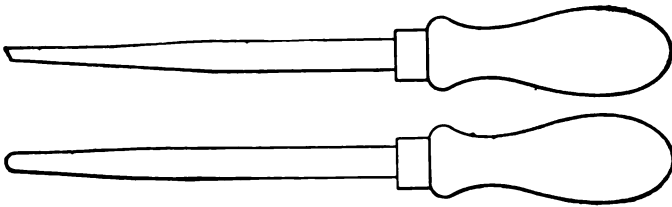
Speed Lathe. The small lathe used in the machine shop for the operations of hand turning, filing, and polishing is called the hand or speed lathe, Fig. 83. This type driven by foot power is in great favor with amateur workmen. While hand turning is avoided as much as possible, it cannot be wholly eliminated, and a brief description of the tools used and the operations performed seems necessary.



Planisher.



Graver.



Round Nose.

Fig. 84.

The tools used on brass and composition cut by a scraping action, and are almost always held at or below the center. The three tools shown in Fig. 84 called the planisher, graver, and round nose, are typical of all the tools necessary for turning brass.

etc. The manner of holding these tools in connection with the T-rest is illustrated by the planisher in Fig. 85. Fig. 86 shows another view of the T-rest. Typical hand tools for cutting iron and steel are the diamond point or graver and the round nose,

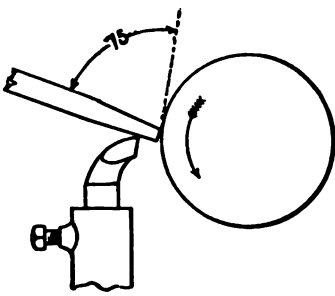


Fig. 85.

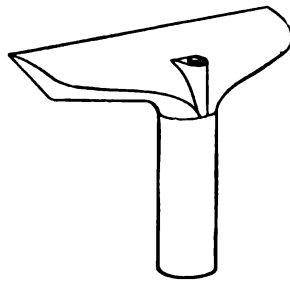


Fig. 86.

shown in Fig. 87. They are used differently from hand tools for brass, in that the cutting edge is carried above the center, and the metal is removed by cutting instead of scraping. The graver

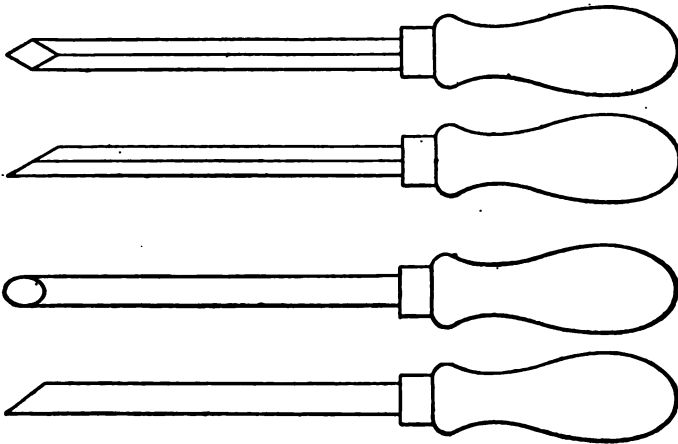


Fig. 87.

frequently takes the place of the planisher, for it can be used as shown in Fig. 88, either on the outside or on the end of a piece of work. The round nose is used solely for concave surfaces, being held as high on the work as proper cutting will allow; Fig.

89. The graver can be used on brass for a great variety of operations; but its use, except in the hands of an expert workman, is attended with danger of catching in the soft metal and thus breaking the tool or spoiling the work.

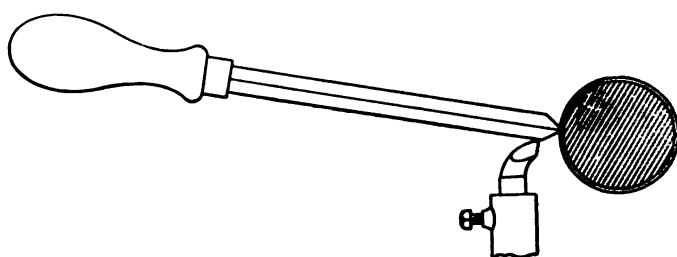


Fig. 88.

To make the hand lathe more rapid and certain in operation, it is frequently provided with a tool holder, called the slide rest, Fig. 90. This holds the tool rigidly and guides it mechanically, so that the work is done more rapidly than with hand tools. Slide rest tools are miniatures of those used on larger lathes, hence a description will not be given at this point.

Engine Lathe. When the slide rest is permanently attached to, and movable along, the bed of the lathe, and motion is auto-

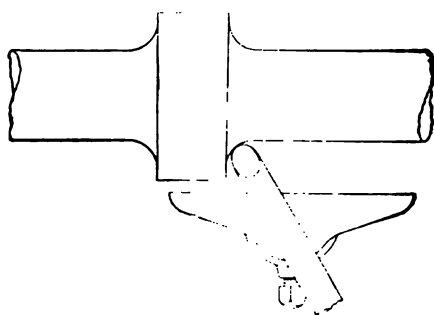


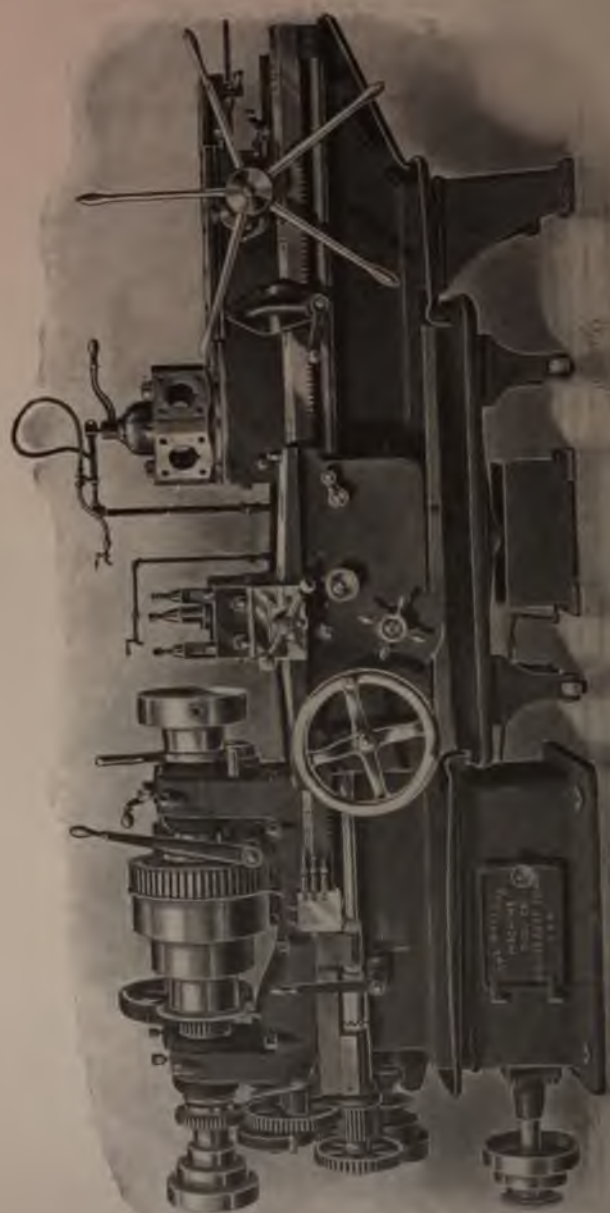
Fig. 89.

matically imparted to the tool, we have what is termed the engine lathe. This is one of the most common, as well as one of the most important machine tools, and one which can be made to serve for a wide variety of operations. For these reasons, it is entitled to a more extended description than

that accorded to less typical forms.

An ordinary form of screw cutting engine lathe is shown in Fig. 91, which is a representation of one of usual dimensions. It has a strong cast-iron bed A, carried on four well braced legs, that

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TURRET MACHINE.

Swing 20 inches. Bed 10 Feet.
The Bullard Machine Tool Co.

may be bolted to the floor, though the weight of the machine may be sufficient to hold it in position. On the left-hand end of the bed there is fastened the head stock B, which carries the main running gear of the machine. At each end of the head stock there is a bearing for the spindle. Running loosely on the spindle and between the bearing is the cone pulley C to which the pinion D is attached.

The back gear is designed to reduce the speed of the spindle without changing the belt speed. The mechanism of the back

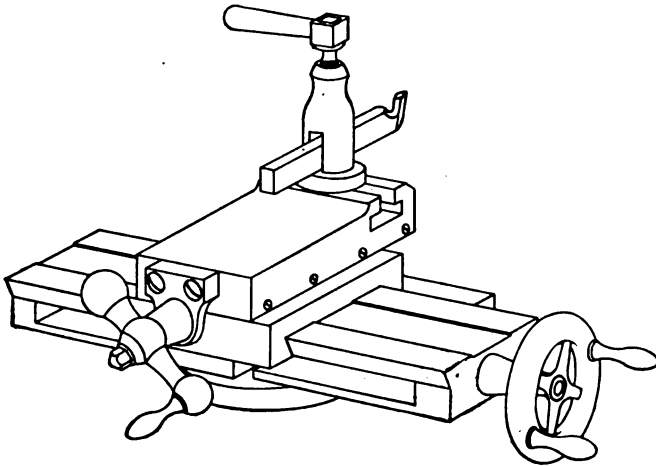


Fig. 90.

gear is more clearly shown in Fig. 92. The large gear E alone shows in Fig. 91. It is driven by the pinion D which is attached to the cone. The pinion on the same sleeve as the gear E drives the gear at the right of the cone. This gear is keyed to the spindle. When the back gear is not in use it is thrown out of mesh with the gears on the pulley and spindle, by means of the shaft having eccentric bearings upon which it turns; at the same time the cone pulley is fastened to the gear at its right. The spindle then turns with the cone pulley. When the back gear is in use the spindle runs more slowly, with the belt on the same step of the cone, than it does when driven direct.

The spindle projects through the bearings at each end. At the right it is usually threaded to receive a face plate F. It is

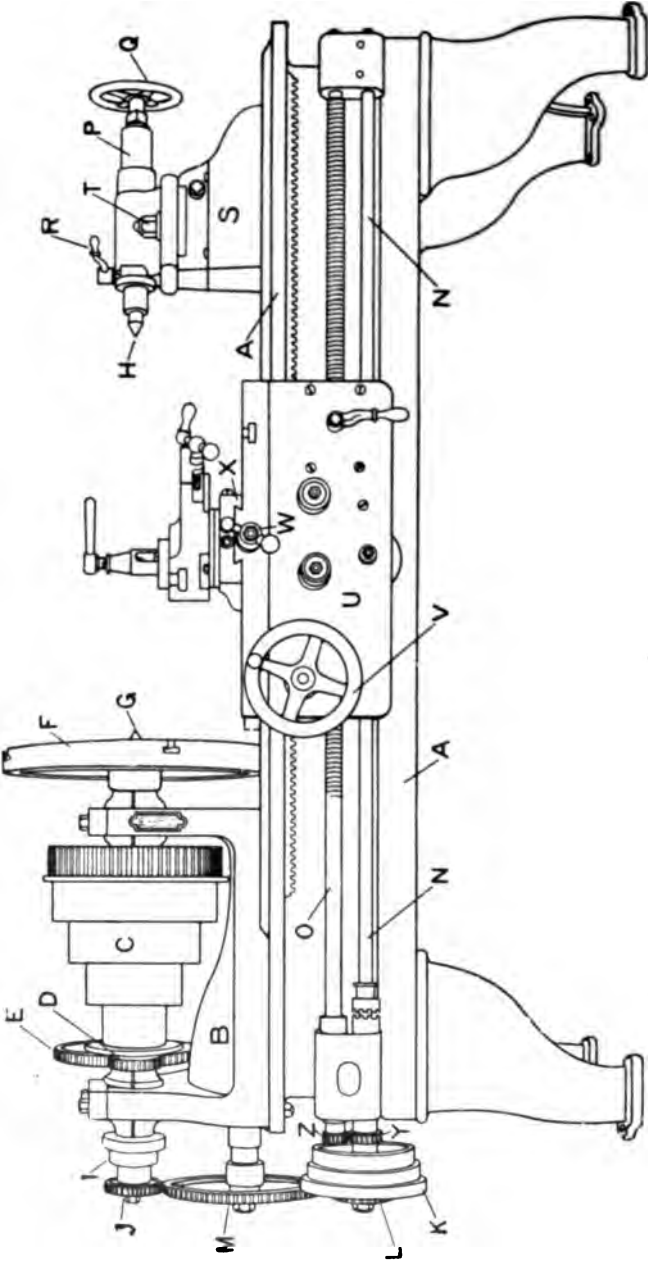


fig. 91.

also bored out and tapered at the end for a center G. This center is called the *live center* because it turns with the spindle. The *dead center* H is in the tailstock, and hence does not turn. At the left the spindle projects beyond the bearings, and carries a small cone pulley I and a pinion J. The cone pulley serves as the driving pulley for a narrow belt running to the corresponding pulley K on the feed rod N. The pinion serves to drive, through the intermediate gear M, the lead-screw O.

The work is held on the centers G and H, the distance between which is adjusted by moving the tailstock S (sometimes called the tailblock). The latter is held to the bed by a clamp and bolts tightened by the nuts T. To move the tailstock, these nuts are slackened and the stock moved to the proper position. The final adjustment is made by turning the hand wheel Q, which rotates a screw in the case P, which works in a nut in the spindle of the dead center H which is thus moved in and out. When the centers have been properly adjusted and the work is in position, the dead center is clamped by the handle R.

When work is to be turned, the tool is properly adjusted, and the carriage U moved along the bed. This movement is accomplished by means of gearing, which is placed behind the apron of the carriage, and driven by the shaft upon which the cone pulley K is keyed. The driving gear meshes with a rack beneath the upper ledge of the bed. Connection between the gearing and the shaft is made by a friction clutch. The carriage may also be moved by hand, by turning the hand wheel V, to which there is keyed a pinion directly meshing in the rack.

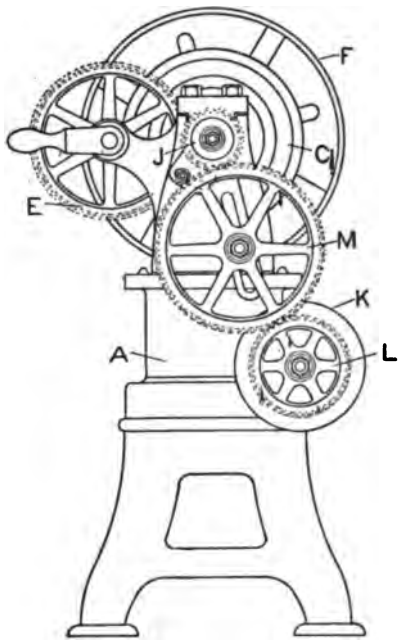


Fig. 92.

The tool is fed to the work and withdrawn from it by turning the cross feed handle W. This drives, by means of the screw and nut, the cross slide X. This arrangement permits any desired transverse or longitudinal position of the tool. The motion of the carriage is usually from right to left when at work. When screws are to be cut, a different feed is used. In ordinary turning there will be a variation in the relations between the rotation of the work and the longitudinal motion of the tool due to the slipping of the belt connecting the cone pulleys I and K, or to the slipping of the friction clutch connecting the shaft K to the driving gear.

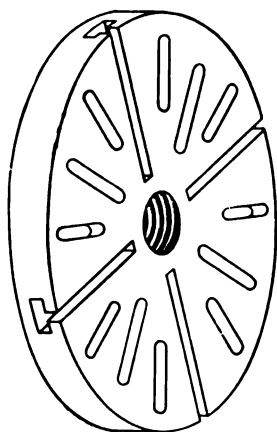
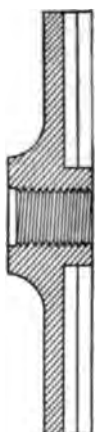


Fig. 93.



To cut a screw thread it is necessary that there shall be no relative change in the rotation of the work and the longitudinal motion of the tool. In other words, the tool must travel a given distance for every revolution of the work. To accomplish this, the carriage is driven by the lead-screw O working in a nut set in the carriage. The screw is, in turn, driven by the train of gears J, M,

and L. The gear J is keyed to the spindle. The intermediate gear M runs loose on a stud. The gear L is keyed to the feed rod N, which transmits its motion to the lead-screw O by gears Y and Z. By changing the sizes of the gears used on the spindle and the screw, any desired thread may be cut. The size of the intermediate gear M has no effect on the thread being cut. It is used to connect the other two gears, and can be adjusted to any desired position for that purpose.

In this country the SIZE OF A LATHE is designated by the largest *diameter* it will swing over the guides, and by the length of the bed. The lathe illustrated is known as 24" $\times$ 8'. In England the distance from the guides to the center is the unit of size, and, in a few cases, the greatest distance between centers is

considered to be the length of the lathe. Thus a 15-inch lathe in England would be a 30-inch lathe in the United States.

The attachments usually furnished without extra charge are a large face plate of the full swing of the lathe, a steady rest, and a follower rest.

The small face plate is used only for driving the work indirectly through suitable attachments. The large face plate shown

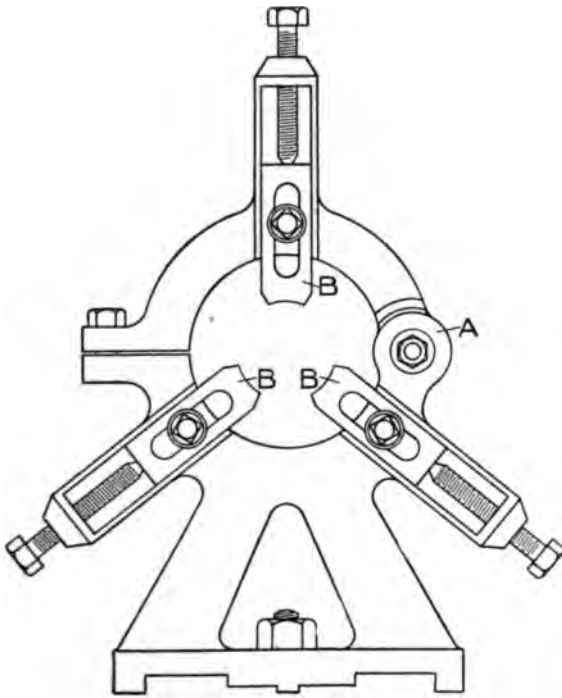


Fig. 94.

in Figs. 91 and 93 is used as a direct support for the work, the T-slots and other openings furnishing opportunities for bolting and clamping the work firmly to the face plate.

The Steady Rest. When work is being done on the end of a shaft so that the tailstock cannot be used, it is necessary to support the shaft in some other way. It is done by means of the steady rest shown in Fig. 94. This rest consists of a frame hinged at A, and fitted with three movable jaws, B B B. The rest is

clamped to the lathe bed in the proper place. The jaws B B B are then adjusted to form a bearing for the work, care being taken that the axis of the work is parallel to the ways, or shears. Unless it is parallel, the work will not be turned true; that is, the end

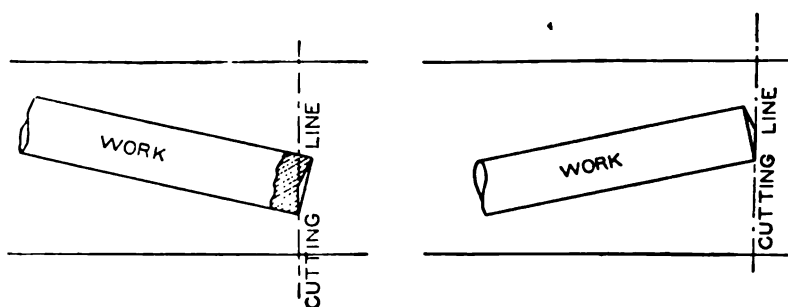


Fig. 95.

will not be square, but will be hollowed or conical, as shown somewhat exaggerated in the accompanying diagram (Fig. 95). The steady rest is also used to support long shafts that are being turned; it prevents such work from sagging at the center and thus being turned out of true.

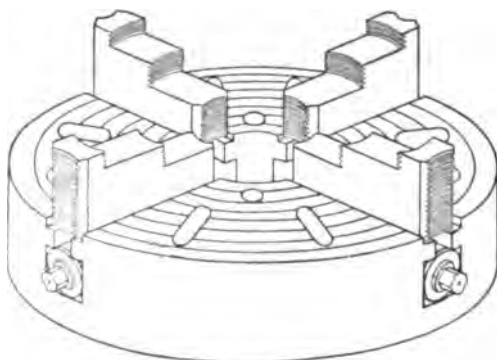


Fig. 97.

After adjusting the steady rest to size, it can be moved along the bed of the lathe without changing the relation to the lathe axis; but care must be taken not to reverse the steady rest in the lathe, as, in most cases, such action would necessitate a readjustment.

The names, back rest and center rest, are synonymous with steady rest, the use of the device often determining the name.

The follower rest serves some of the purposes of the steady rest, but is fastened to the carriage, and moves with it at the point of greatest stress. It may consist of adjustable jaws or a solid ring to slip over the piece being turned. It is especially

valuable in turning shafting and other work where the ratio of length to diameter is very great. The follower rest is not very often used in shop practice, except on classes of work just mentioned. The extra attachments desirable for a lathe will now be briefly described.

Chucks. First in importance is the lathe chuck, Fig. 96. It consists of a body which is fastened to a special face plate in such

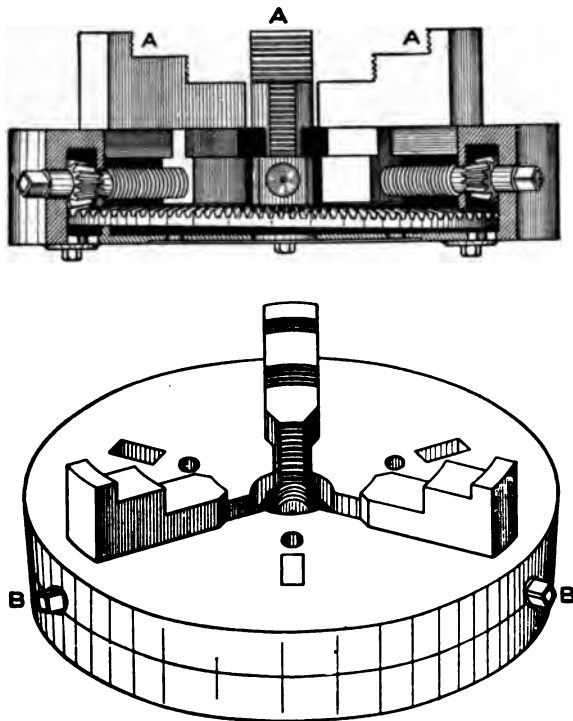


Fig. 96.

a way that it is concentric with the spindle. The three jaws AAA can be moved in and out toward the center by turning the screw-heads BBB. These chucks are universal or independent. In the universal chuck all of the jaws are operated simultaneously. That is, when one of the screw heads B is turned, all of the jaws are moved an equal distance towards or away from the center. This makes it possible to put the work in position quickly if it is approximately round in its unfinished condition. With the in-

dependent chuck, Fig. 97, each jaw is operated separately. Such a chuck is used for holding pieces of irregular shape and those which must be held eccentrically. Frequently the universal and independent chucks are combined in one. Means are then provided for working the jaws separately or together as desired.

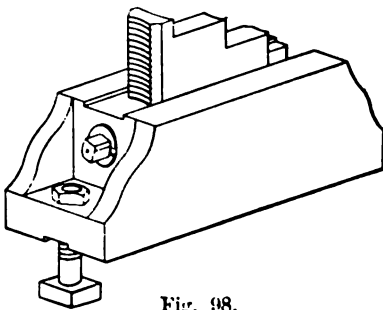


Fig. 98.

In using the universal chuck each screw should be tightened. The method of procedure is to place the work in the chuck, and turn one screw head until all of the jaws are in contact with the piece to be operated upon. Then turn the chuck and tighten each screw head successively

until each one is tight enough. Owing to wear and lost motion, it is sometimes necessary to apply the wrench to each one three or four times before the final adjustment is reached.

Lathe chucks are usually made with three or four jaws. Universal chucks generally have three jaws, while independent chucks have four. It follows that a combination chuck is not wholly satisfactory, because with three independent jaws it is very difficult to adjust work accurately, and with four universal jaws it is equally difficult to get every jaw to bear on the work. For certain classes of work, especially valves and pipe fittings, chucks with two jaws are often used.

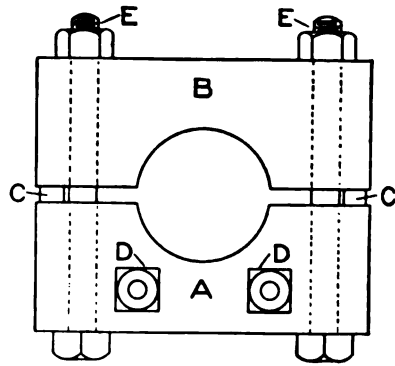


Fig. 99.

The large face plate of a lathe can be made into an independent chuck by attaching what are known as face-plate jaws; Fig. 98. In this case, there may be six, eight, or more jaws.

As these chucks are expensive it sometimes happens that a

piece is to be held for which no provision is made. A chuck can then be made of wood. Such a chuck is shown in Fig. 99. Two pieces of wood, A and B, are bolted together by the bolts EE, while separated by the filling pieces CC. The piece is firmly bolted to a face plate by the bolts DD. The lathe is then run at high speed; and the interior bored out exactly the size of the piece that is to be held. The nuts of the bolts EE are slackened and the filling pieces CC removed. The work is then inserted,

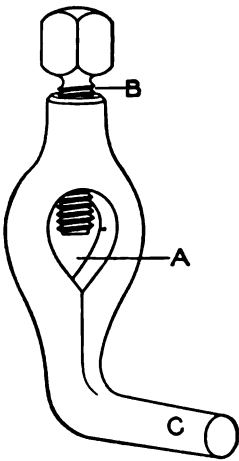


Fig. 100.

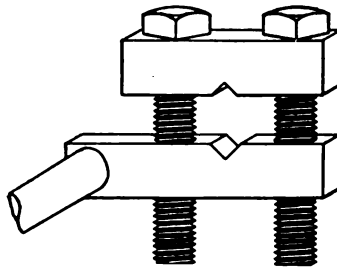


Fig. 101.

and by tightening the nuts EE, it is securely clamped between the pieces A and B.

Lathe Dogs. As the frictional contact of the work on the live center is not sufficient to turn it, some device must be used to make the work turn with the center. To accomplish this a lathe dog is used. For round work, such as shafting, a dog like that shown in Fig. 100 is often used. The shaft or piece to be turned is placed in the hole A, and held firmly in place by the set screw B. The tail-piece C is put through a hole in the face plate and the work rotates with the live center.

While this type of dog is satisfactory in most cases, the fact that the contact between the dog and the face plate is beyond the end of the piece, introduces a bending strain which is appreciable

in slender work. To avoid this, dogs are made with a straight tail, and driven by a stud projecting from the face plate.

For work other than round, a dog such as that shown in Fig. 101 may be used. The work is placed between the jaws, and held in position by the bolts. The holes in the upper jaw are made

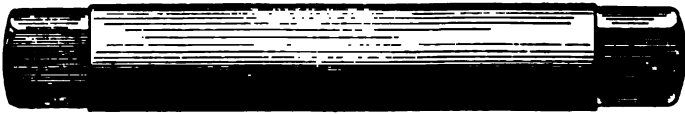


Fig. 102.

larger than the screws in order that the angle between the jaws may be varied. The connection between the face plate and dog is made as with Fig. 100.

Mandrels. Another method of holding work is by the use of a mandrel. This is a piece of steel with a slight taper; the ends

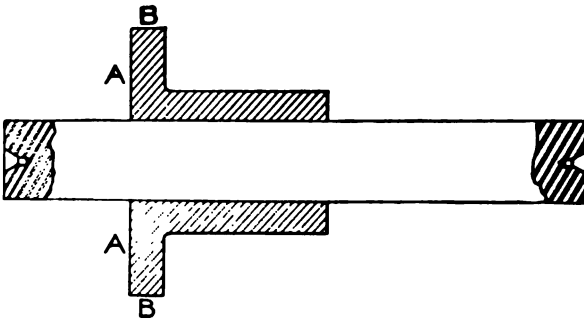
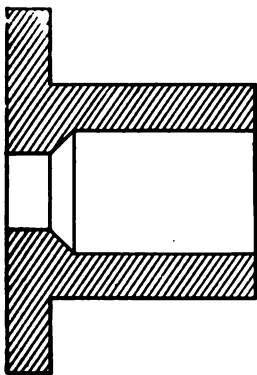


Fig. 103.

are flattened for the lathe dog, as shown in Fig. 102. It frequently happens that a piece with a hole in it is to be turned or finished over its outer surface. In this case a dog cannot be used, and it is troublesome to hold it to a chuck. Such a piece is shown in Fig. 103. This is a stuffing-box gland. If it were to be held by the jaws of a chuck the face A could not be reached at all, and only a portion of the edge B, whereas a dog clamped to it would offer even greater obstruction. The method of using the mandrel is to ream the gland out, so that it can be driven upon

the mandrel. When this has been done the frictional resistance between the two will be sufficient to drive the piece. In this manner it can be finished over its whole surface with but one setting in the lathe. All finishing possible may be done while it is in the chuck, leaving, in this case, only the face A and edge B to be finished while on the mandrel.



Should the gland be shaped, as shown in Fig. 104, it would be necessary to make a special mandrel to fit the bore. The cylindrical part of A of the mandrel must be a driving fit, and the part B a loose fit.

Expanding Mandrels. Where a mandrel like that shown in Fig. 102 is frequently used, the constant driving on and off of the work will wear it to a smaller diameter, causing it to become useless. Again, solid mandrels are usually made of standard diameters, varying by sixteenths of an inch.

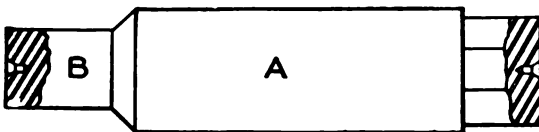


Fig. 104.

It sometimes happens that a piece to be turned has a hole which will not fit any standard solid mandrel.

To overcome these difficulties an expanding mandrel, shown in Fig. 105, is used. This is really a chuck so arranged that the grips can be forced out against the interior of the hole. When the work has been finished the grips are again drawn in and the piece removed. Another form of expanding mandrel is shown in Fig. 106.

Centering. A piece to be turned is supported on the two centers of the lathe. In order that this may be done, the ends are prepared by drilling a hole in each and countersinking it. This is called centering the work. The countersink should be of exactly the same angle as the lathe center upon which it is to run. The hole should be drilled deep enough so that the point of the lathe center may not strike. The shape of the hole is

shown in Fig. 107. The angle of the hole varies from 40° to 90° , but 60° is the generally accepted standard. The effect of using a 60° hole on a 90° center is shown in Fig. 108. The result of such an application is that the bearing will be concentrated on a

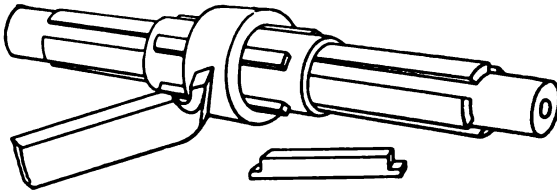


Fig. 105.

line AB causing rapid wear of the outer end of the hole, and a cutting of the dead center.

The size of center holes varies with the weight of the work and the character of the operation. Heavy work and rough turning require large center holes, while small work and fine turning can be done without countersinking deeply. As bearing surfaces in cast iron must be large to be satisfactory, center holes in cast iron are likely to give trouble by unequal and rapid wear. When turned work in cast iron must be very accurate, it is well

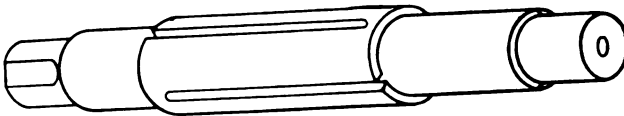


Fig. 106.

to drill a large hole in each end, drive in a plug of wrought iron or mild steel, and form the center holes in the plugs thus driven.

When the piece has been put in place, the dead center should be oiled and screwed up into position. It should be tightened so that there is no lost motion and yet allow the work to turn freely.

The turning of shafts and bars is not, however, the only kind of work to be done on a lathe. Pieces are to be turned that are thin, that have holes through the center, and which are so shaped

that they cannot be held upon the centers. In such cases it becomes necessary to hold the work firmly without distortion, as may be done by use of the lathe chuck.

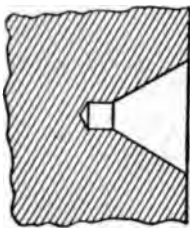


Fig. 107.

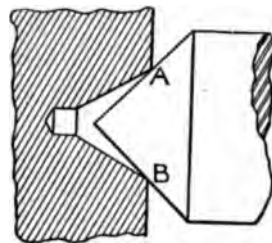


Fig. 108.

Still another method of holding work is that shown in Fig. 109. The piece is clamped to the face plate. When this is done there should be a bearing on the face plate immediately beneath the clamping strap. For example consider Fig. 110. Suppose a disk having four feet on one side is to be faced off on the front.

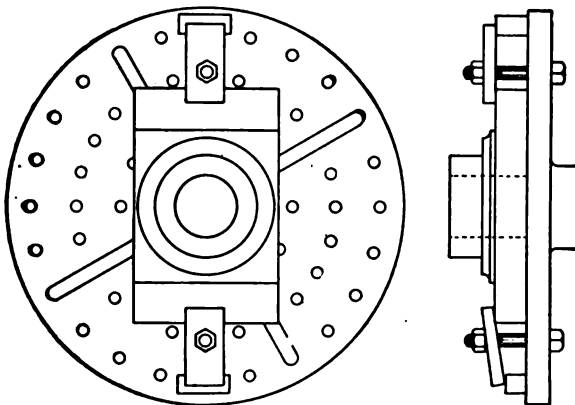


Fig. 109.

The clamps should be placed directly over the feet as in B. If they are placed between the feet at EE the work will be sprung out of shape as shown by the dotted lines in A. Then, when the tool has done its work the shape of the piece, while bolted to the

face plate, will be as shown in C. As soon as the pressure of the straps is removed the elasticity of the metal will cause the piece to assume the convex form shown in D, whereas, if the straps had been placed as shown in B, no distortion would have been produced.

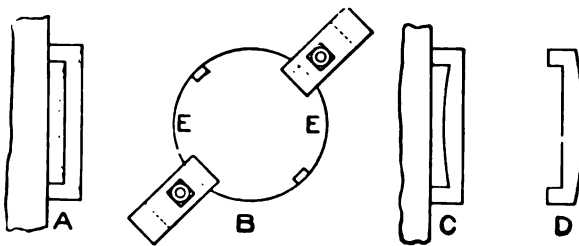


Fig. 110.

An angle iron may be clamped on a face plate, as shown in Fig. 111, presenting a surface parallel to the lathe axis to which work may be attached. The angle irons may of course be at any angle to the face plate, but 90° is the one most commonly used.

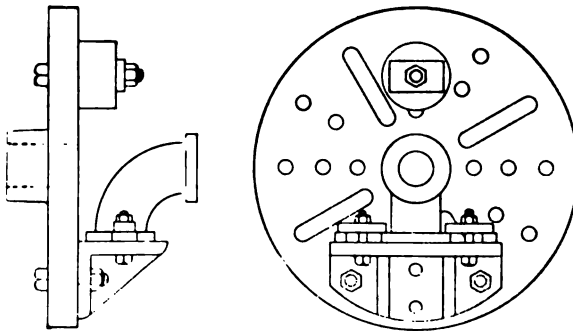


Fig. 111.

When work is held in this manner, it is desirable to counter-balance it, as is also shown in Fig. 111.

Adjusting Pieces to Center. Whenever a piece is to be turned in a lathe it is necessary to adjust it so that its rough outline is approximately concentric with the lathe centers. This is

done by bolting it lightly to the face plate and running the lathe. While running, a piece of chalk is held so that the projecting portions will strike it. This marks the piece, and indicates the part that is *farthest* from the center. The lathe is then stopped and the piece shifted, *moving the chalk mark towards the lathe center*. This is repeated until the chalk makes a continuous mark around the whole circumference. The piece may then be considered to be centered.

Suppose it is necessary to center a piece having a hole that must run true. In this case the inside of the hole must be used as a guide. Let Fig. 112 represent the hole with the thin shell, and A a chalk mark made as described for centering by the outside. In this work the *chalk mark must be moved away from the center*.

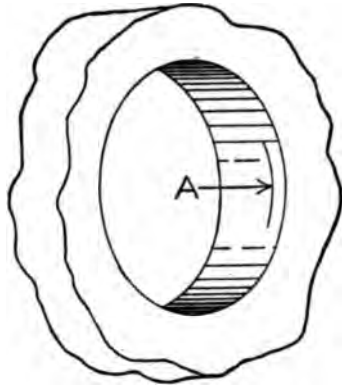


Fig. 112.

A lathe tool may be used as shown in Fig. 113 to center a piece that is to be bored.

Where a piece has already been turned, greater accuracy is demanded, and a surface gage may be used to advantage. Set the gage on the bed or carriage of the lathe, and place one of the points in contact with the work. Rotate the work as before, and note where the point touches the surface. This point is to be treated in the same way as the chalk

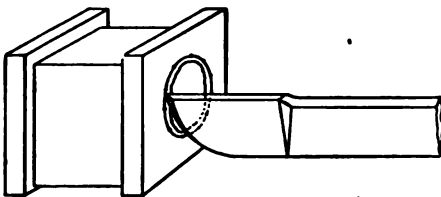


Fig. 113.

mark explained in a preceding paragraph.

A still more accurate method of centering a piece of turned work on a face plate is to use some form of graduated indicator, such as the Starrett indicator, Fig. 114. This is held in the tool post, and the contact point brought against the work until the indicating arm is at zero. If the work is now slowly rotated by

hand, the indicator will show just where the work is out of true, and being graduated in thousandths of an inch, will also show how much. By careful adjustment, the piece may be centered to the degree of accuracy required.

Instead of locating a cylindrical surface concentric with the axis of the lathe, it often happens that a point is to be located in the axis. For this purpose, the center indicator, Fig. 115, is used. The free end of the short arm is placed in the point to be centered (usually a prick punch mark), the fulcrum being held in

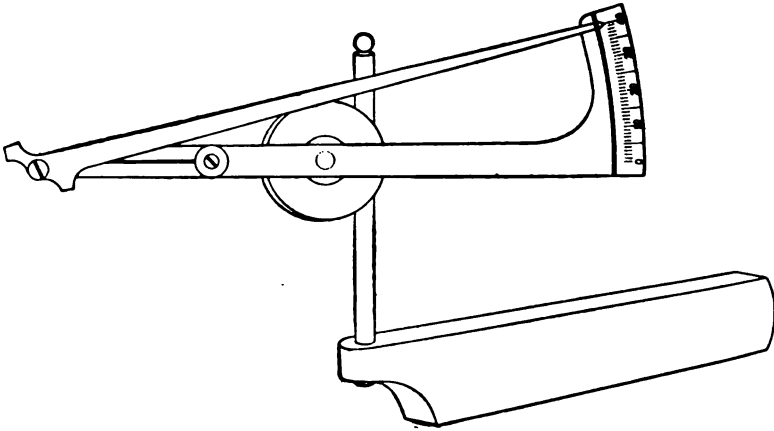
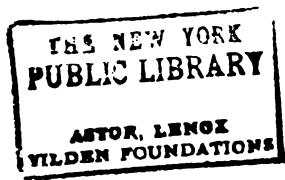


Fig. 114.

the tool post; when the work is rotated, the free end of the long arm not only shows the error, but magnifies it in proportion of the length of the short arm to the length of the long arm. By using a comparatively long arm, the point can be very closely centered.

Centering Finished Work. After making the center punch mark in the end of the piece, it is drilled and countersunk. This must be done very accurately, but frequently the drilled hole or the countersink will not be in the exact center. See Fig. 116. This may be caused by uneven grinding of the drill, eccentric motion of the drill point (due to the inaccurate running of the spindle), or the distortion of the metal by the center punch. If the countersink is not exactly in the center, it must be drawn back to the center. This is generally done by the small round-





42-INCH POND LATHE.
Niles-Bement-Pond Company.

nosed chisel and a hammer. The method of doing this work is as follows: After making the center punch mark, the hole is drilled and then countersunk slightly. The work should now be

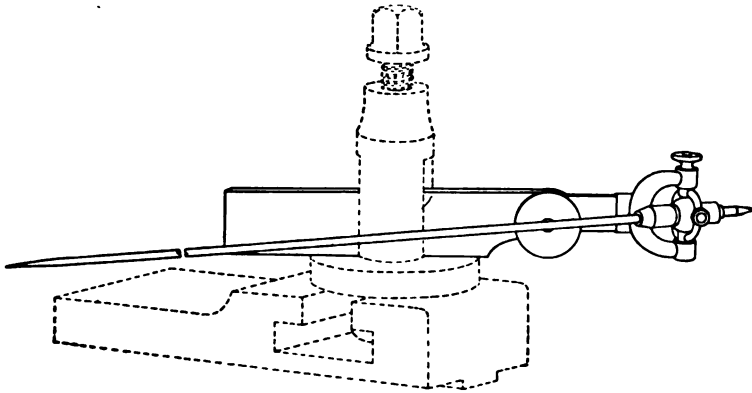


Fig. 115.

stopped; and if the circumference of the conical hole is not concentric with the circumference of the piece a groove should be cut down the side farthest from the outer circumference, as shown in Fig. 117. The depth of the groove, which should be near the

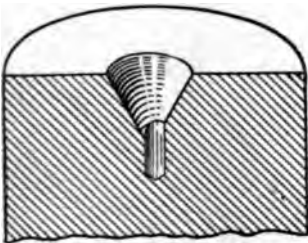


Fig. 116.

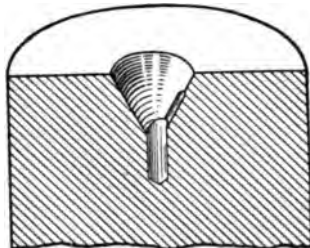


Fig. 117.

center, depends upon the amount of eccentricity. The countersink is again started and the groove drilled out. If the circle is not yet concentric, the process is repeated.

Lathe Tools. The cutting tools used in lathes are of a great variety of shapes. These shapes are adapted to the work that is to be done, and to the kind of finish that is to be left upon the

metal. There are two fundamental requirements that all tools must fulfill: *The cutting edge alone must touch the metal; the edge must be keen.* A typical form of tool is shown in Fig. 118. The cutting edge of the tool at A is in contact with the work.

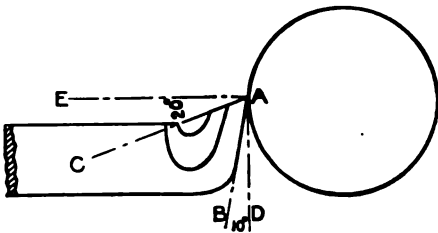


Fig. 118.

The bottom line A B runs back from the metal and does not touch it. The top face A C slopes down and back. The line A D is a tangent at the cutting point, and the line A E is radial at the same point.

Therefore, the angle D A E is always a right angle or 90° . The angle D A B is called the angle of *clearance*, and should be small; in lathe tools, not over 10° . The angle C A E is called the angle of *rake*, and should be as great as circumstances will permit; about 20° on lathe tools for wrought iron and steel, leaving 60° for the *solid* or *cutting* angle, which is the same angle as is used for a cold chisel.

Clearance prevents the tool from rubbing on the work, while rake adds to the keenness of the cutting edge, and gives freedom

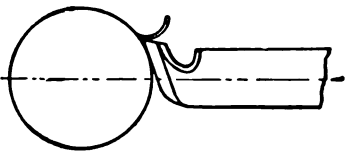


Fig. 119.

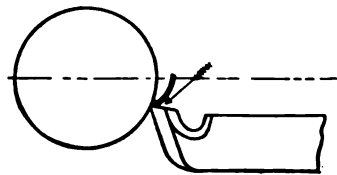


Fig. 120.

to the removal of the chips. A tool should have sufficient strength at the point to do the work required.

The tool should be set so that the cutting edge will be very nearly at a horizontal line, passing through the axis of the work. Many machinists set the cutting edge a little above the horizontal line. When so set the stress tends to force the tool down along the line of its greatest strength. The tool may, however, be set

too high. If this is done, as in Fig. 119, the angle of clearance will disappear, and the curve of the work will rub against the bottom of the tool. This will tend to force it out; it will heat the steel and produce a rough surface on the metal being turned. If, on the other hand, the tool is set too low, as in Fig. 120, the cutting edge does not stand in line with the motion of the work at the point of contact.

The result will be that the metal will be scraped rather than cut, as there is no rake, and the pressure upon the tool will be in the line of its lowest power of resistance, as indicated by the arrow. Such a position

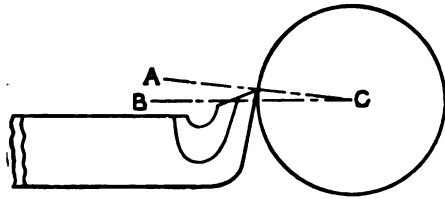


Fig. 121.

might cause the point of the tool to break off. It will also cause the tool to tremble or chatter as it removes the chips, leaving a rough and wavy surface on the metal.

As stated above, many machinists prefer to set the cutting edge a little above the center; if this is done, the rotation of the work

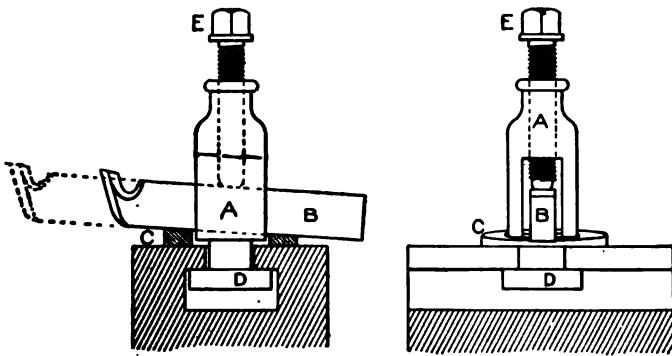


Fig. 122.

has a tendency to depress the point of the tool a little, bringing it, while cutting, nearly to the center. The amount the tool is set above the center is slight, and of course depends upon the character of the work. The angle A C B, Fig. 121, should be only about 5 or 6 degrees.

The tool is usually held to the carriage by means of a tool post, shown in Fig. 122. The post consists of a piece with a slotted hole through the center for the tool B. A ring C slips over it and rests upon the body of the carriage. This ring may be

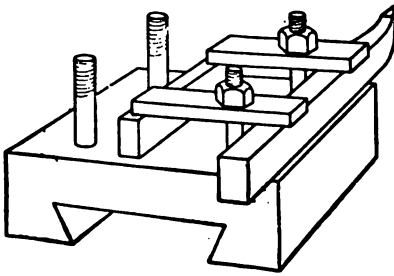


Fig. 122.

beveled as shown, to provide vertical adjustment for the point of the tool. The post has a collar D at its lower end that goes loosely into a slot in the carriage. At the top there is a set screw E. When the tool has been properly adjusted by turning the ring C to give it the correct elevation, the set screw is

tightened down upon the top of the tool. This raises the tool post to a bearing on the under side of the slot, and clamps the whole carriage firmly in position.

In setting the tool, it should be done with the cutting edge as far back towards the supporting ring as possible. If it has too much overhang, as shown by the dotted lines of Fig. 122, it will spring under the pressure of the work and chatter.

While this form of tool post is used more than any other, there are certain objections to it. In the first place, changing the

height of the tool point also changes the angles of rake and clearance. These are supposed to be correct when the base of the tool is horizontal. Any change from this position will alter these angles materially. Again, this post is not rigid enough for heavy work. On lathes of over thirty inches swing the style of tool-holder shown in Fig. 123 is often employed.

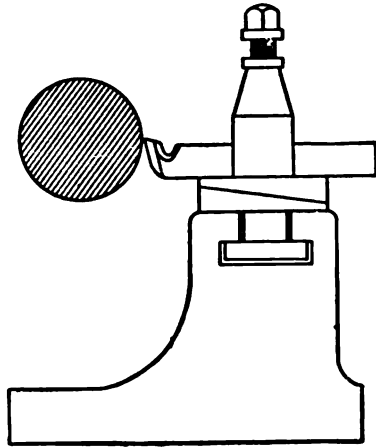


Fig. 124.

English manufacturers use it almost exclusively on all sizes. There is no provision for raising and lowering the point of the tool; and while this is not of serious importance on large lathes, 30-inch and over, it becomes a matter of moment when turning such work as is usually handled in lathes of 14-inch and 16-inch swing.

The form shown in Fig. 124 has two beveled rings to adjust the height of the tool.

The Lipe tool post, shown in Fig. 125, combines the good points of all the other forms; the tool can be held by one or two

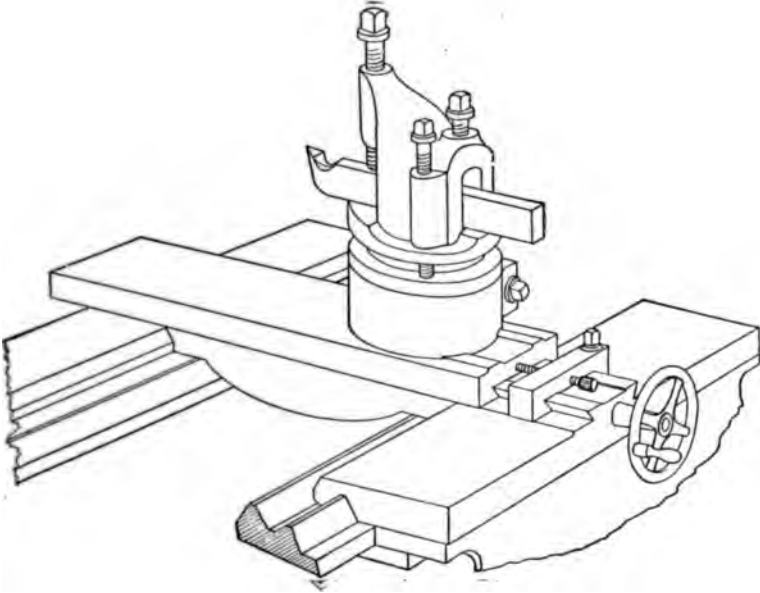


Fig. 125.

screws as the character of the work may require, and the tool may be adjusted vertically and horizontally after being clamped down. The construction and operation of this tool post are so evident from the illustration, that further description will not be given.

An entirely different method of adjusting the tool point is by means of what is called the elevating or rise-and-fall rest shown in Fig. 126. In this type there is a T-shaped casting carried on the upper part of the carriage, supported by trunnion screws at

the front, and by an adjusting screw at the rear. With this is used a tool post as shown in Fig. 122 with a plain ring. The elevating rest is used quite extensively on small lathes, but the convenience of adjustment is gained by a loss in rigidity. The cross rail is light, and the elevating portion, being supported at three widely separated points, lacks stiffness. As the effective swing over the carriage is limited by the height of the cross rail and the parts carried above it, they are made light — too light in many cases.

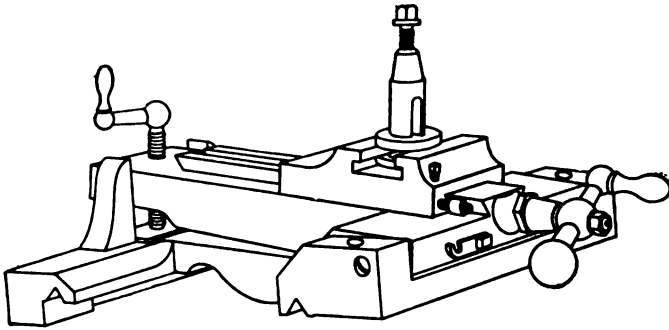


Fig. 126.

Turning Tools. The side or facing tool, Fig. 127, is the most common form of lathe tool. It is used for squaring up the ends of shafts, facing shoulders, and similar work. While the ordinary forms will not remove a large amount of metal, they can,

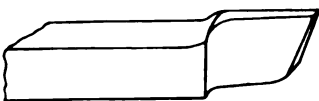


Fig. 127.

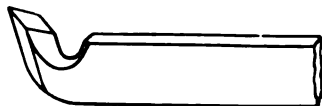


Fig. 128.

when made thick and heavy, be used for roughing cuts on the surface of cylindrical work. The common form is made slender in order to work between the dead center and the work in squaring up ends.

A common form of tool for turning wrought iron and steel is the diamond point shown in Fig. 128. The name is derived from the shape of the top face. This tool has both front and side rake

which allows a keen edge without reducing the strength. It is used for finishing only when the point is ground slightly rounding and a fine feed is used. In finishing, but little metal should be removed. The *Feed* of a tool is the amount of longitudinal advance at each revolution of the work. For roughing out cast iron, a strong and rapid working tool is a round nose with considerable side rake. For finishing wrought iron and steel, a modification of the diamond point, as shown in Fig. 129, is often

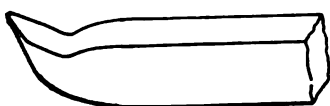


Fig. 129.

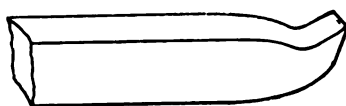


Fig. 130.

used. For cast iron, a square-nosed tool, Fig. 130, should be used. It must be carefully ground and accurately set, otherwise it is very likely to gouge into the softer parts of the metal. When finishing wrought iron and steel, the tool should be liberally supplied with oil or soda water. Cast iron must always be worked dry, both in roughing and finishing.

The cutting-off or parting tool is illustrated in Fig. 131. The blade is quite narrow; as narrow, in fact, as the character of the work will allow. This is necessary in order that the stock may not be wasted. As the blade must be narrower at the shank

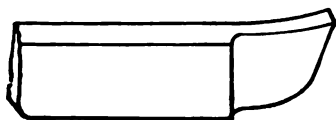


Fig. 131.

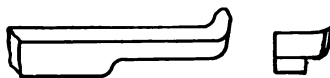


Fig. 132.

and at the bottom than it is at the cutting edge, it follows that the tool is weak. It must be set horizontally so that, as the tool is fed to the work, the cutting edge only will touch the metal. It must also be set so that the cutting edge will pass through the axis of the work as it is fed to the center. If set too high, it will cease to cut before the center of the work is reached, while if too low, the tool has a poor scraping action, and will leave a portion of the work uncut. On work held between centers, one should not

attempt to cut to the center of the piece, as the work will surely ride up onto the tool.

Boring Tools. When a hole is to be bored in a lathe, tools of a different shape from those used in turning must be used. The general form of the tool is shown in Fig. 132. The length of the shank at A depends on the depth of the hole to be bored, for it must be long enough to reach from the tool post to the bottom of the hole. This overhang makes the tool more likely to spring, and necessitates a much lighter cut than can be taken when removing the same amount of metal by outside turning tools. The result of this lighter cut is seen in the increase of time required to remove a given amount of stock. The shape of the cutting edge is practically the same as that of the tools for turning, except that the boring tool must have more clearance to avoid striking the work. Therefore, with the same solid angle, the tool will have less rake. The reason for this will be seen by compar-

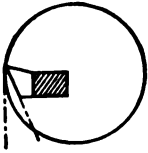


Fig. 133.

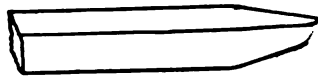


Fig. 134.

ing Figs. 118 and 133. In Fig. 118 it will be seen that the surface of the work is outside a tangent at the cutting point, and can never interfere with the bottom of the tool. In Fig. 133 the work surface is inside the tangent; and, unless the tool has a large amount of clearance, it will cause trouble by striking the concave surface.

Tools for brass differ from those used on steel and iron in that they have no rake. A tool suited for brass is shown in Fig. 134. Brass is a very brittle metal, and the chips break off as soon as started from the main body. When turning wrought iron and steel, on the other hand, the metal does not break, but forms long spiral chips if the tool is in good condition. If a tool with rake is used in turning brass, the work will not only be rough in appearance, but there is great danger of the tool gouging into the stock and spoiling the work or tool, possibly both. The finishing

tools for brass may be square or round nosed, without rake; in fact, a small amount of negative rake will produce a much better surface. When the brass contains a large percentage of copper, some rake may be required owing to the ductility and toughness of the metal.

Fig. 135 shows common forms of lathe tools.

The shape of the tool has a very important influence on the amount of work it can be made to do. As has already been ex-

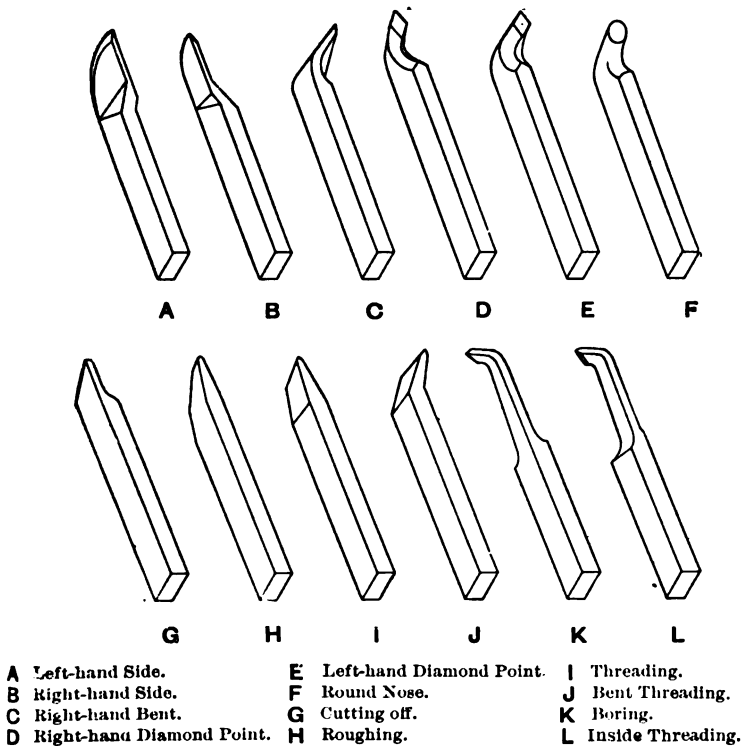


Fig. 135.

plained, these shapes vary with the different metals that are being worked, and also with the class of work performed. It is highly important that the cutting angles be correctly formed. While hand grinding on the emery wheel and grindstone is fairly satisfactory, the best results can only be attained by the use of a regular tool-grinding machine, shown in Fig. 136. In addition,

tools for fine finishing should be carefully whetted on a fine oil stone.

The cutting speed is an important matter. This varies with the shape of the tool, the quality of the metal being worked, and the strength of the lathe. The amount of metal removed in a given time is therefore equally variable. It is impossible to make a correct estimate of the time that a given piece of work will require unless all of the above elements are known. For approximate estimates the speeds of cutting tools may be taken to range about as follows:

It cast iron.	from 15 to 40 feet per minute.
It wrought iron.	from 25 to 50 feet per minute.
It steel.	from 15 to 25 feet per minute.
It brass.	from 40 to 100 feet per minute.

Suppose a wrought shaft 6 feet long and 4 inches in diameter is to be turned. Let the lathe be capable of carrying a feed of $\frac{1}{16}$ inch per revolution. The shaft has a circumference of $4 \times 3.1416 = 12.5664$ inches. To give the tool a cutting speed of 25 feet per minute, the shaft must make $\frac{25 \times 12}{12.5664} = 24$ (about) revolutions, giving a feed of $\frac{1}{16} \times 24 = \frac{3}{2}$ inch in that interval of time. At $\frac{3}{2}$ inch per minute, it will take $(6 \times 12) \div \frac{3}{2} = 96$ minutes to take a cut the whole length of the shaft. The amount of feed is really the governing element. This may be as much as $\frac{1}{16}$ inch per revolution, and, for finishing cuts, may not be more than $\frac{1}{160}$ inch. The depth of the cut also influences the time required to finish a given piece. This may vary from $\frac{1}{16}$ to $\frac{1}{2}$ inch. All depends on the shape of the tool and the strength of the lathe.

The cutting speeds given above are what may be used with the best grades of tool steel, such as Jessop's, but by using air-hardening or tungsten steels, the speed of cutting may be very much increased over the values given above. These high-speed steels are rapidly coming into favor, more especially for heavy roughing cuts. Not only are the cutting speeds increased, but

is made heavier both in depth and feed up to the point the lathe refuses to carry the load. The ability of this steel to stand high temperatures without injury is the which enables it to do work at this rate.

For cooling the tool while performing heavy duty, a solution of sal soda is preferable to water, as it prevents rusting of the work and machinery. The lubricant does not assist in the severing of the metal; even with a most liberal supply, it is doubtful if any ever reaches the point of the tool. Its office is simply to

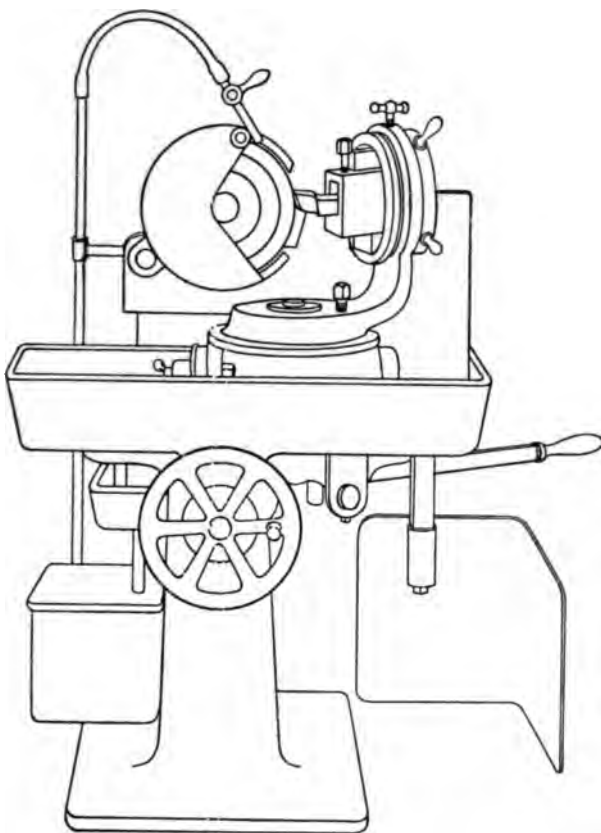


Fig. 136.

keep the tool cool. If a tool becomes overheated, the edge begins to turn over and it becomes dull.

Referring to Fig. 120, it will be seen that the chip, as it is being removed, presses down on the top face of the tool. This pressure increases with the depth of cut and the feed. The friction would soon cause a high temperature in the tool if it were

not relieved by the lubricant. The lubricant cools the tool by absorbing a portion of the heat, and lessens the amount of heat developed by reducing the friction between the tool and the chip. Clean, pure water is the only lubricant which can be used on cast iron, but the rapid rusting which follows its use makes it undesirable. Brass is also usually turned dry. Prime quality lard oil is sometimes used for cooling the tool; but the greater cost prevents its extended use, unless some means are provided to collect, separate, and filter it.

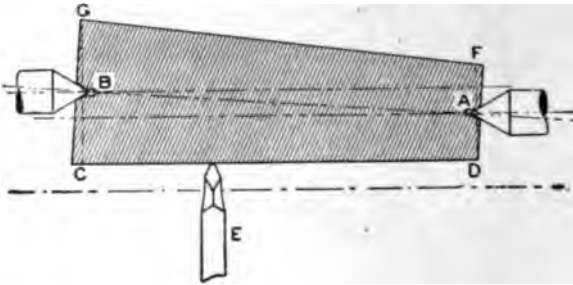


Fig. 137.

Turning. The first operation usually performed on a piece of work when placed in the lathe is facing or squaring up the ends. This must be done to get a uniform bearing for the centers. The finishing of all surfaces at or nearly at right angles to the axis of the work is classed as facing, and the side tool (Fig. 127) is usually employed. For roughing cuts the cutting face of the tool is placed at a slight angle to the work surface in order to remove the metal quickly; but for finishing cuts it is placed nearly flat against the work, so that a light thin chip may be taken.

Turning the cylindrical portions of the work is next done by the use of the diamond point or similar tool. Roughing cuts are taken to within about $\frac{1}{64}$ inch of the finished size, and a fine finishing cut reduces the work to the exact diameter. For roughing cuts, common calipers should be employed, while for finishing cuts, the micrometer caliper is most suitable. All measurements must be taken with the lathe at rest, as motion of the work renders close calipering impossible.

Turning a Taper. It frequently happens that a piece must be turned tapering; that is, one end is to have a greater diameter than the other. There are three ways of accomplishing this result: setting the dead center over, the use of the compound rest, and the use of the taper attachment. Setting the dead center over is the most common method. Provision is generally made for moving the dead center laterally towards the front or rear of the bed according to the taper required. With the dead center set over, the tool will be at unequal distances from the live and dead centers, because its movement is parallel to the axis of the lathe. This is shown in Fig. 137. The piece to be turned is placed upon the centers A and B, and the dead center is moved from the axis a distance equal to the difference between the radii A D and B C. This leaves the side D C parallel to the center line of the lathe; hence the tool will be fed along this line. The objection to doing work by this method is that the lathe centers do not have full bearings at the ends of the work, and the center holes are likely to wear out of their true positions.

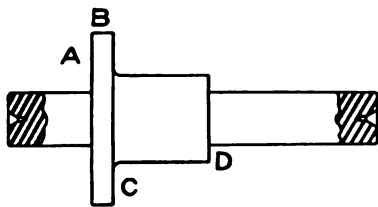


Fig. 138.

If the taper is to be turned on a piece held by a mandrel, or if the taper is to extend but a part of the total length of the work, the amount of set-over for the dead center must be calculated in the same manner as though the taper were to extend the whole length of the mandrel or work. In other words, the amount of set-over for the dead center is determined by the distance between the centers and the rate of taper.

For example: Suppose the mandrel in Fig. 138 to be 16 inches long, and the piece of work C D which is to be turned tapering, is 4 inches long; suppose also, that the diameter at D is to be $\frac{1}{4}$ inch smaller than at C. Then for one inch of length, the difference in diameters would be one-fourth of $\frac{1}{4}$ inch, or $\frac{1}{16}$ inch, and for a length of 16 inches it would be sixteen times $\frac{1}{16}$ inch, or 1 inch. Since the set-over is equal to the difference of the radii, the set-over for the 16 inches would be one-half of 1 inch, or $\frac{1}{2}$ inch.

This, then, would be the set-over for the work under consideration, and for any piece to be tapered at the rate of $\frac{1}{4}$ inch in 4 inches when held on a 16-inch mandrel.

EXAMPLES FOR PRACTICE.

1. A tapered bushing 3 inches long and of 4 and $4\frac{1}{2}$ inches outside diameters is driven on a 12-inch mandrel for turning. How much must the dead center be set out of line in order to do the work? Ans. 1 inch.

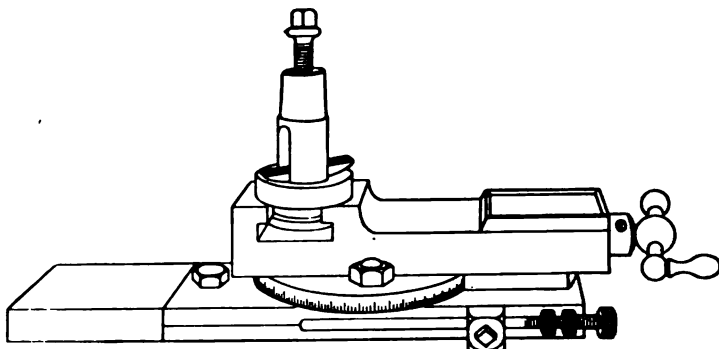


Fig. 139.

2. A connecting rod 6 feet long is to be turned tapering from the center to the neck back of the stub-ends. This distance is 26 inches. The diameter at the center is to be 3 inches, and at the neck $2\frac{1}{2}$ inches. How much offset must be given to the dead center? Ans. .692+ inches.

3. A shaft had a taper 2 feet long turned on one end. The large end of the taper was 4 inches in diameter, and the small end was 3 inches in diameter. The dead center was set over 1 inch. How long was the shaft? Ans. 4 feet.

The machinist generally sets over the dead center as accurately as possible and takes a roughing cut. The taper is then tested by a careful comparison of the diameters or by trying it in a tapered hole of the proper angle, and the center set more accurately. Setting over the dead center does not give accurate results, on account of the fact that the centers do not have a true

bearing at the ends of the work. The shorter the work, compared with the amount of set-over, the greater the inaccuracy.

In turning a taper with the compound rest, the work may be held in a chuck, on the faceplate, or between the centers. The compound rest, Fig. 139, is then set at such an angle that the direction of the motion of the tool will coincide with the required taper. Several methods are employed for this adjustment of the rest. The tool is then fed to the work by means of the feed handle attached to the compound rest.

The taper attachment, Fig. 140, is in the form of a guide which is bolted to the back of the lathe. It can be set at any desired angle with the axis of the lathe, the limit usually being a taper of about three inches per foot. The guide is graduated so

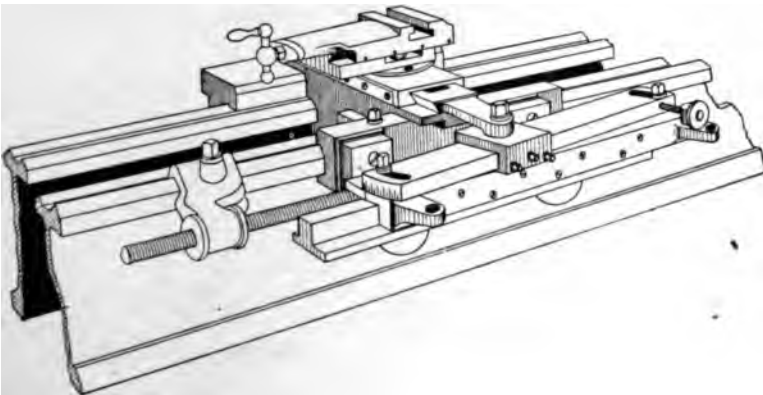


Fig. 140.

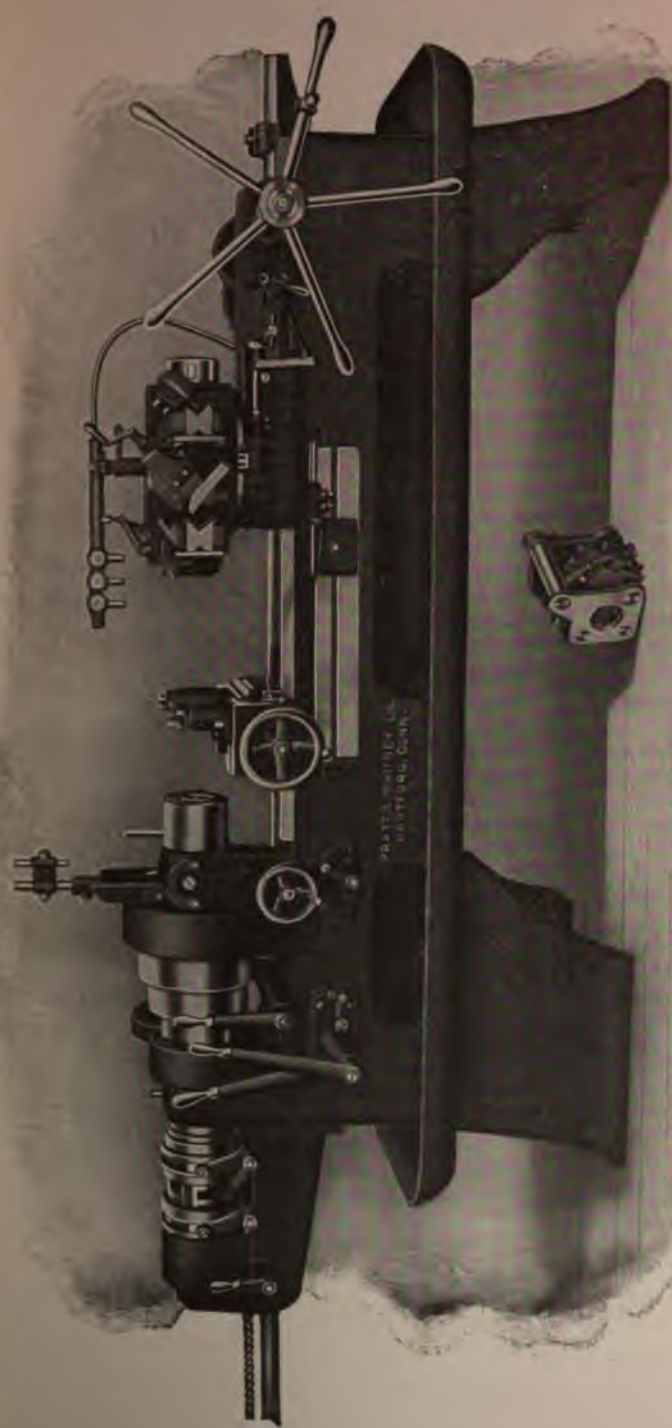
that calculations based on the length of the work are unnecessary. A slide moving with the guide is attached to the cross-feed of the carriage. The cross-feed is loosened, and, while the carriage is moved by the feeding mechanism, the tool is moved in or out according to the direction of the taper.

One of the most important points to be observed in turning tapers is to have the cutting point of the tool exactly level with the centers. If this is not done, the work will not be truly conical, and, furthermore, the rate of taper will vary with each succeeding cut.

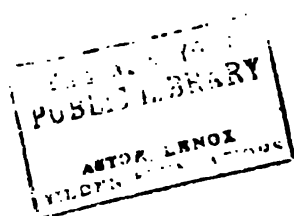
In case an internal and an external taper are to be turned so as to form a fit, the internal taper should, if the character of the work will permit, be made first. After this has been done, the external taper should be turned and tested several times during the process. The external taper is first turned as accurately as possible, taking care that the piece be made a trifle too large. Draw a chalk line on the external taper, from one end to the other, press the tapers together, and give one of them a slight twist. On separating the tapers, the rubbing of the chalk will show where the work was in contact, and, by resetting the lathe and repeating the process, a very accurate fit can be obtained.

Shafting is usually turned $\frac{1}{16}$ inch less than the nominal diameter. For instance, instead of a shaft 2 inches in diameter, one of $1\frac{15}{16}$ inches in diameter is used. The reason is that iron of a nominal diameter of 2 inches, usually $\frac{1}{32}$ inch over size, can be used. Before turning a length of shafting, the rough bar should be carefully straightened. After the center holes have been drilled and the piece placed in the lathe, the work can be turned and the eccentric portions marked with chalk. When this has been done, the bar should be removed from the lathe and sprung back into true alignment. It is well to take two cuts for finishing shafting, one for the roughing cut and one very fine finishing cut. The tool for the latter part of the work should be kept flooded in oil, or a solution of sal soda. If the work is light, a tool-holder, carrying both the roughing and the finishing tools, should be used. This makes it possible to do the work in what practically amounts to the time of one cut.

As a length of shafting is likely to spring under the pressure of the tool, some method of preventing such action must be employed. A steady rest can be used. It is, however, inconvenient and must be frequently moved or it will stand too far, at times, from the tools. Furthermore, as the rough bar will neither be truly round nor concentric with the centers, it is necessary to turn "spots" for the center rest. This operation takes considerable time, owing to the fact that very light cuts must be taken in order to avoid springing the bar. The best method is to have a ring attached to the tool-holder; the internal diameter of this ring is that of the finished shaft. It is slipped over the tail-stock cen-



2 x 26-INCH TURRET LATHE
Pratt and Whitney Co.



ter and follows the finishing tool. It must, of course, be rigidly fastened to the tool-holder. In this way the shaft is supported close to the tools; the ring also serves as a guage to measure the diameter of the shaft. If, for any reason, the tools turn to a larger diameter than the inside of the ring, notice is immediately served upon the workmen to that effect by the binding in the ring.

Eccentric Turning. Up to this point, the work described for the lathe has been of the kind in which the turning is done on work concentric with the lathe centers. There are other classes of work that are offset and for which special provisions must be

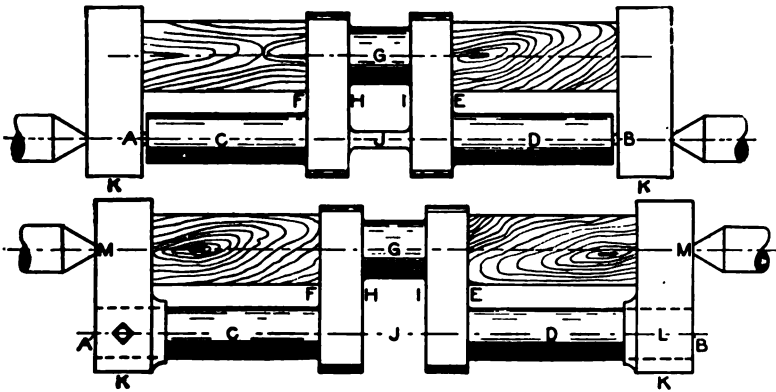


Fig. 141.

made. Of course the surface being turned must always be concentric with the spindle.

The turning of crank shafts presents conditions where there are two cylindrical portions, each parallel to and concentric with the lathe axis while being turned, but eccentric with regard to each other. In Fig. 141 such a shaft is shown. This may be either a casting or a forging. If cast, it is common to have a small web, shown at J, in the original casting to take the thrust of the centers while turning the shaft portions C and D. After centering the work at A and B, the shaft is placed in the lathe, and the ends A and B squared up, and surfaces C and D roughed out. If a forging is being worked, it will be necessary to insert a wooden block at the point J. Two lugs or ears K are provided

to fit tightly on the rough turned shaft, the distance from the center of L to the center M being equal to one-half the throw of the crank. These lugs are attached to the ends of the shaft, so that a line joining the centers M will pass through the axis of the crank pin G. Blocks are now placed between the lugs and the crank pin, the web or block at J removed, and the pin turned

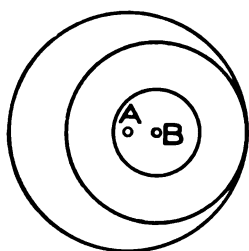


Fig. 142.

on the new centers MM. The crank pin G is roughed and finished, and the shoulders H and I faced, at this time. Removing the lugs and blocks, the surfaces C and D are finished and the shoulders E and F faced on the centers A and B. If the shaft is of any considerable weight, it should be counter-balanced by attaching weights to the faceplate. The reason for not finishing the shaft at the first operation

tion, is that removing the scale from a casting or the outer skin from a forging releases internal stresses which are likely to change the shape of the piece. As a general rule, a piece of work should be completely roughed out, if possible, before any finishing cuts are taken. The change in shape, due to the removal of the outer portion of the stock, does not all take place immediately; and, if very accurate results are desired, it is good practice to allow the roughed work to stand some time before finishing.



Fig. 143.

Turning an Eccentric. As far as its use in mechanism is concerned, an eccentric is the equivalent of a small crank, but it requires very different treatment in the lathe. In the first place, it is not usually made solid with the shaft, but is a comparatively thin casting or forging which is fastened to the shaft by set screws or keys. The general shape is shown in Fig. 142, and

consists of the eccentric proper and a boss to reinforce the shaft hole ; this boss usually being on but one side of the casting. In Fig. 142, A is the center of the eccentric and B the center of the shaft.

Small eccentrics, especially those having a throw less than the diameter of the shaft, may be finished in the following manner: The casting is grasped in an independent chuck, one having four jaws being preferred, with the boss or hub running as nearly true

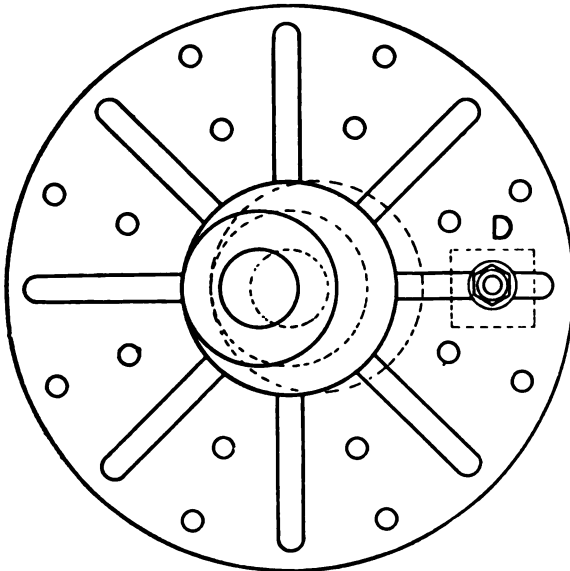


Fig. 144.

as possible. The projecting face of the eccentric, together with the outside and face of the hub, may be machined, and the hole can be trued up with a boring tool or by the use of the chuck drill and reamer. In either case, it is advisable to obtain the exact diameter by using a finishing reamer. The eccentric may now be placed on a special mandrel, shown in Fig. 143, which has an extra set of center holes. A line connecting these holes is parallel to the axis of the mandrel, and at a distance from it equal to one-half the throw of the eccentric. It is obvious that this mandrel is the equivalent of the shaft and lugs used in turning solid crank

pins. On these extra centers the outside of the eccentric may be turned, and, on the regular centers, the back or plain face can also be finished. This completes the eccentric as far as the lathe is concerned.

Large and heavy eccentrics are preferably finished on a faceplate. The plain side or back having been previously machined, the eccentric is clamped to the faceplate with the hub running true, shown dotted in Fig. 144, and the face of the hub and the

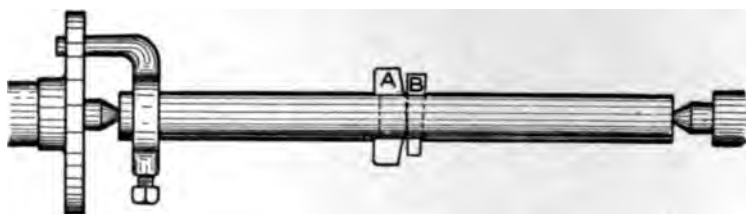


Fig. 145.

hole are finished as in the case of the small eccentric held in the chuck. The diameter of the hole being comparatively large, a reamer is not generally used. The eccentric is now moved on the faceplate a distance equal to one-half the throw of the eccentric, bringing the outer surface concentric with the lathe axis, as shown by the full lines, and the clamps placed so as to allow the outside to be turned. It is often necessary to balance the work by counterweights, in order to have the lathe run steadily. This is shown at D in Fig. 144.

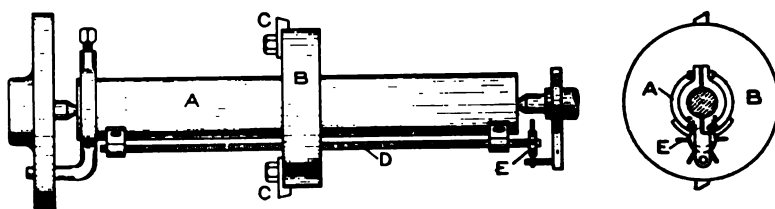


Fig. 146.

Boring. The boring of holes sometimes calls for a length and strength of tool that cannot be readily attained with the ordinary boring tool. A great deal of such boring is done with double-headed tools. These tools are held in bars and cut at each end. An ordinary form of such a tool is shown in Fig. 145.

The tool A is turned and fitted so that when placed in the bar it is central with the centers of the latter. It is held in position by the key B. It cuts at each end. Such a tool may be made to do very rapid work. It is extensively used for boring in places where a piece of work must be duplicated a great number of times.

Tools of this character are used for finishing. After the cut has been started the tool should not be stopped until the cut has been completed. If it is stopped there will be a ledge in the bore at that point. The reason for this is due to the springing of the metal and the contraction due to cooling while at rest. The tools used for finishing usually have a broad surface. Those used for

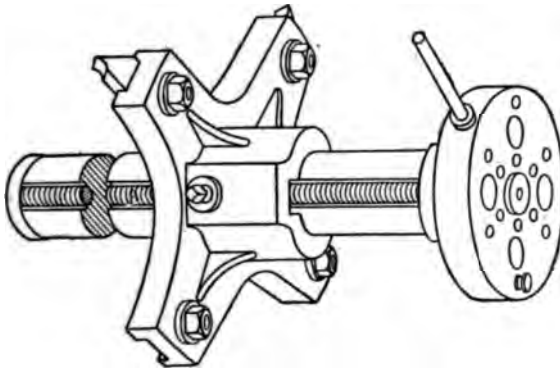


Fig. 147.

the roughing-cut are narrower; they wear more rapidly than the finishing tools and are usually adjustable. A roughing tool may be held by a wedge as shown at B. Such a tool is placed in position and the wedge tightened just enough to hold it. The adjustment of the tool is then obtained by tapping it with the hammer. It is then held firmly by driving the wedge. An excellent example of this style of work is found in the boring of engine cylinders. Special machines are used for such work. The greater portion of it, however, is done in an ordinary lathe with a boring bar, as shown in Fig. 146. It consists of a heavy bar A, upon which there is a stiff traveling head B. The latter carries the tool C, which may or may not be capable of a transverse adjustment. The head moves longitudinally over the bar and is held,

adjusted and fed by the screw D. At one end of the screw there is a star wheel, E, by which it is turned. As the bar revolves, one arm strikes against a stop at each revolution. This turns the screw by an amount proportional to the number of arms in the star. For example, if there are six arms in the star, the latter will be turned one-sixth of a revolution for each revolution of the boring bar. As the screw turns, it moves the head along the bar by an amount proportional to the pitch of its thread and the rays or arms in the star. This forms the feed of the tool. For example, if a star has four arms, and is keyed to a screw of eight threads to the inch, then for each revolution of the bar the head will be advanced $\frac{1}{2}$ of an inch. Another form of boring bar is shown in Fig. 147.

Boring bars with fixed tools are also used. In such cases the work is caused to travel beneath the bar as it is turned. A case of this kind occurs in the boring out of brasses for railroad cars.

It may be stated that, in general, all metal work should be finished in the position which it is eventually to occupy. This is

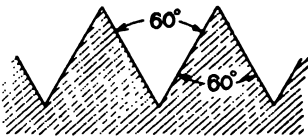


Fig. 148.

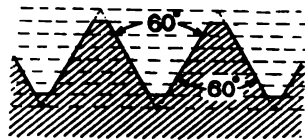


Fig. 149.

due to its tendency to spring out of shape under the influence of its own weight. For small articles this influence is inappreciable. For large pieces it is sometimes quite apparent.

SCREW CUTTING.

The tools used for cutting threads are called *screw-cutting tools*. These tools are used in the lathe in the same manner as the diamond point and round-nosed tools. The cutting edge of the tool must be of the same shape as the space between the finished threads.

There are five types of screw threads commonly used in this country: the V thread, shown in Fig. 148, has the form of an

equilateral triangle with an angle of 60° . It is sharp at the top and bottom. This thread is difficult to cut because of the trouble experienced in keeping the point of the tool sharp.

A modified form of V thread, known as the Sellers, the Franklin Institute, or the United States Standard, is shown in Fig. 149. This thread has an angle of 60° , with the top and bottom flattened for one-eighth of its depth. It is stronger than the V-shaped thread, and permits greater accuracy in cutting.

Another form in common use is the square thread. This is shown in Fig. 150. The thread and space are of the same width. These screws are

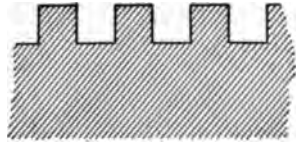


Fig. 150.

used when heavy work is done, such as in jack-screws and presses.

The Whitworth thread is similar to the United States Standard; the slight differences are as follows: the sides form an angle of 55° instead of 60° , and the top and bottom are rounded instead of flat.

The fifth type, the Acme thread, is similar to the square form. The difference is that the sides incline $14\frac{1}{2}^\circ$ from those of the square thread. This form of thread is much used for lathe

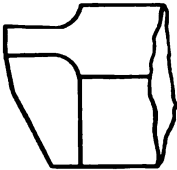


Fig. 151.

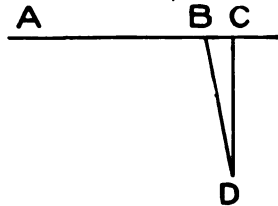


Fig. 152.

lead screws and for giving motion to sliding parts of fine instruments, because the thread is much stronger than the square form, and the lost motion can be taken up by simply closing the nut halves nearer together.

The tool used for cutting square threads is shown in Fig. 151. It is of the proper thickness at the cutting edge, but is somewhat narrower back of this point. The sides of the tool are inclined to the body, as shown at A B, Fig. 151; the amount of

this inclination varies with the pitch of the thread and the diameter of the piece on which the thread is to be cut. To find the inclination, draw an indefinite straight line A C and at right angles to it draw C D. Make the length of C D equal to the circumference of the thread to be cut, measured at the root of the thread. On A C lay off from C a distance (B C) equal to the pitch; then draw B D. This line will represent the angle of the side of the thread. The angle of the side of the cutting tool must be a little greater for clearance.

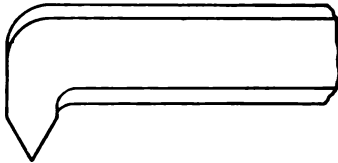


Fig. 153.

For cutting *inside* threads, the shape of the cutting edge of the tool should be the same as for cutting an outside thread, but the tool must be made so that the cutting edge alone touches the work.

This is accomplished by bending

the tool as shown in Fig. 153 and giving it considerable clearance.

Standard Screw Threads. When screw threads are to be cut, the pitch used depends upon the outside diameter of the bar. A standard has been adopted by all of the leading technical societies of the United States, and is known as the United States Standard. The table (see opposite page) gives the outside diameter of the screw from $\frac{1}{4}$ inch to 6 inches in diameter, with the number of threads per inch to be cut.

In placing the tool for any form of thread, the point of the tool must be exactly level with the center, and a line at right angles to the axis of the lathe must bisect the angle of the tool point. In order that these conditions may be fulfilled, a thread or center gauge, Fig. 154, is used. In this tool, the angles, A, B, and C are made exactly 60° . The two opposite sides are parallel. The angle A at the end is used for grinding the tool. The sides of the latter are made to touch all along the edge. For setting the tool, the upper parallel side is held against the face of the work in a

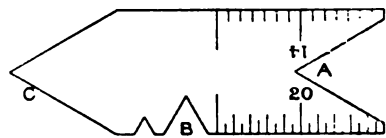


Fig. 154.

horizontal position. The tool is then set so that its sides touch along the edges of the notch B. The angle C is used to gauge the thread after it is cut.

UNITED STATES STANDARD SCREW THREADS.

DIAMETER OF SCREW IN INCHES.	NUMBER OF THREADS PER INCH.	DIAMETER OF SCREW.	NUMBER OF THREADS PER INCH.
$\frac{1}{16}$	20	2	$4\frac{1}{2}$
$\frac{3}{16}$	18	$2\frac{1}{4}$	$4\frac{1}{2}$
$\frac{1}{4}$	10	$2\frac{1}{2}$	4
$\frac{5}{16}$	14	$2\frac{3}{4}$	4
$\frac{3}{8}$	13	3	$3\frac{1}{2}$
$\frac{7}{16}$	12	$3\frac{1}{4}$	$3\frac{1}{2}$
$\frac{1}{2}$	11	$3\frac{1}{2}$	$3\frac{1}{2}$
$\frac{9}{16}$	10	$3\frac{3}{4}$	3
$\frac{5}{8}$	9	4	3
$\frac{3}{4}$	8	$4\frac{1}{4}$	$2\frac{7}{8}$
$\frac{7}{8}$	7	$4\frac{1}{2}$	$2\frac{3}{4}$
1	7	$4\frac{3}{4}$	$2\frac{3}{4}$
	6	5	$2\frac{1}{2}$
	6	$5\frac{1}{4}$	$2\frac{1}{2}$
	$5\frac{1}{2}$	$5\frac{1}{2}$	$3\frac{1}{4}$
	5	$5\frac{3}{4}$	$2\frac{3}{4}$
	5	6	$2\frac{1}{4}$

The measurement of fine threads is a difficult matter where an ordinary rule is used and the threads between the inch marks are counted. For this purpose a pitch gauge, Fig. 155, is used. The gauges are short screw sections on thin sheets of metal. To ascertain the pitch of any thread, set the gauges over it successively until one is found that exactly fits. The figures stamped thereon will give the number of threads per inch.

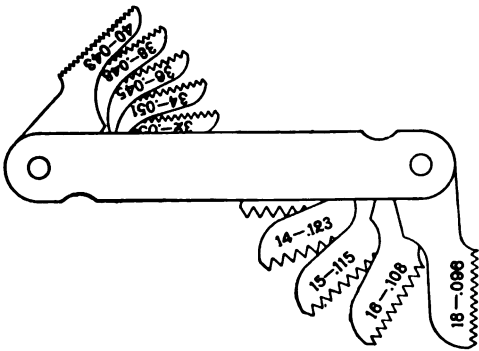


Fig. 155.

The cutting of a thread demands that there shall be a certain definite ratio of motion between the rotation of the work and the

travel of the carriage. When a right-handed screw is to be cut, the carriage travels from right to left. For example, if a screw having a pitch of $\frac{1}{4}$ inch, or with four threads to the inch, as it is usually expressed, is to be cut, the spindle must make four revolutions while the carriage is moving one inch along the bed. If the screw is to have eight threads to the inch, the spindle must make eight revolutions to each inch of motion of the carriage or tool; if six threads, then six revolutions to the inch of motion, etc.

If, then, the lead screw is cut with four threads to the inch, it is evident that the speed of rotation of the spindle and of the screw must be the same, in order to cut a screw of four threads to the inch. For each revolution of the lead screw, the carriage moves the distance of the pitch of the same or $\frac{1}{4}$ inch. Hence, the gears, J and L, Fig. 91, must have the same number of teeth. When a screw of eight threads per inch is to be cut, the spindle must make twice as many revolutions as the lead screw. Then, for each revolution of the spindle, the lead screw makes half a revolution and thus moves the carriage $\frac{1}{2}$ inch. In this case, the screw gear L must have twice as many teeth as the spindle gear J. For six threads, the ratio of revolutions between spindle and screw is $1\frac{1}{2}$ to 1. This requires $1\frac{1}{2}$ times as many teeth in the screw gear L as in the spindle gear J.

The rule for finding the gears to be used on the spindle and lead screw is: Multiply the number of threads on the lead screw and the number of threads to be cut by the *same* number; the products will equal the numbers of teeth on the gears to be used.

Suppose the lead screw has four threads per inch, and ten threads per inch are to be cut. Multiply both numbers by any convenient number, such as 3. Then the gears should have 12 teeth and 30 teeth.

Let a = the number of threads per inch on the lead screw,

b = the number of threads per inch to be cut,

c = a convenient number,

$a\ c$ = the number of teeth of gear on spindle,

$b\ c$ = the number of teeth of gear on lead screw.

If the gears thus found are not at hand, multiply by some other number. Thus, suppose gears of 30 and 12 teeth were not

available, multiply 4 and 10 by 4 or by 5 or any other number that would give the number of teeth on the gears at hand.

Another way to find the gears is to remember that the number of threads to be cut is to the number on the lead screw as the number of teeth on the screw gear is to the number of teeth on the spindle gear.

EXAMPLES FOR PRACTICE.

(1) The lead screw has a pitch of $\frac{1}{4}$ inch. What is the ratio of gears to be used to cut a screw with 9 threads to the inch? If one gear has 24 teeth, how many should the other have?

Ans. $\left\{ \begin{array}{l} 1: 2\frac{1}{4} \\ 54 \text{ teeth.} \end{array} \right.$

(2) The lead screw has a pitch of $\frac{1}{4}$ inch. What is the ratio of gears to be used to cut a screw with 16 threads to the inch?

Ans. 1: 4.

(3) The lead screw has a pitch of $\frac{1}{8}$ inch. What is the ratio of gears to be used to cut a screw with 12 threads to the inch?

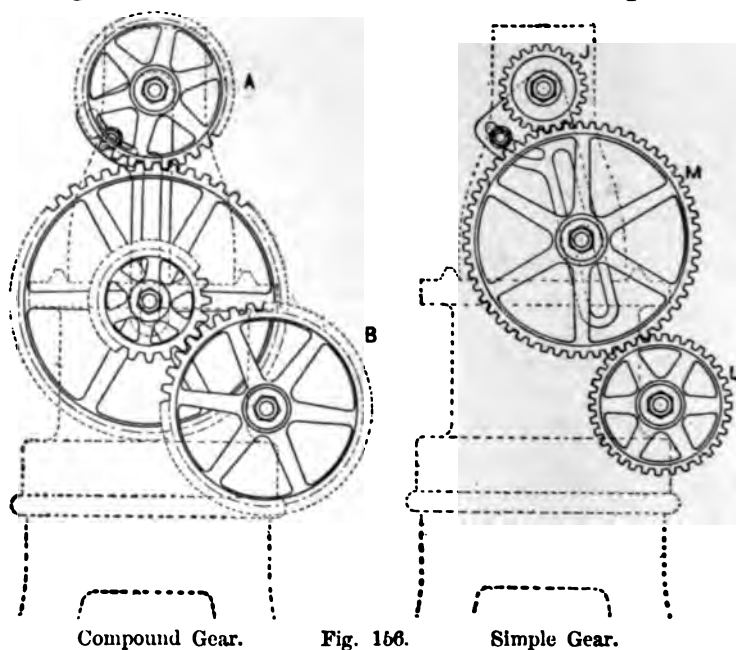
Ans. 1: 4.

In these cases the actual number of teeth on the gears to be used is obtained by multiplying the ratio by some common multiple. Thus in example 1, multiplying by 10 gives 40 teeth for the spindle gear and 90 for the screw gear. In example 2, multiplying by 20 gives 20 teeth for the spindle and 80 for the screw gear; and the same result is obtained by using the same multiple for example 3.

Every screw-cutting lathe is provided with a set of gears from which selections can be made. In order to facilitate the choice of the gears to be used, a *gear table* is usually cast in raised letters and screwed to the front piece of the headstock. This table shows the gears to be used for cutting such threads as may be enumerated on the table.

It is sometimes necessary to cut a screw for which there are no gears to make a direct connection. This necessitates the compounding of the gears on the intermediate spindle to replace the single gear. This is done as shown in Fig 156, in which A represents the spindle and B the screw. Suppose, with a lead

screw having three threads to the inch, it is desired to cut a screw having thirteen. This makes the ratio of teeth on the spindle gear to those on the screw as 3 to 13. The work can be done with spindle gears having 15, 30, or 45 teeth with screw gears having 65, 130, and 195 teeth respectively. If it is found that there are no gears having 15, 45, 130, or 195 teeth on hand, compounding must be resorted to. To determine the gears to be



used it must be remembered that *the product of the numbers of teeth in the driving gears must be to the product of the numbers of teeth of the driven gears, as the number of threads per inch on the lead screw is to the number to be cut.* In this case it is as 3 to 13. Multiply each of these figures by any convenient multiple. In the example in hand, let the multiple be 200. Then

$$\frac{3 \times 200}{13 \times 200} = \frac{3 \times 2 \times 2 \times 2 \times 5 \times 5}{13 \times 2 \times 2 \times 2 \times 5 \times 5}.$$

Select from the factors thus obtained two sets, each of which, when multiplied together, will give products equal to the number of teeth that are on hand.

Thus in the numerator we may take $3 \times 2 \times 5$ and $2 \times 2 \times 5$, giving 30 and 20 as gears that are to be used as the spindle and intermediate drivers respectively.

For the denominator take 13×5 and $2 \times 2 \times 5 \times 2$ or 65 and 40, for the driven gears of the intermediate stud and the screw respectively. Placing these in position as in Fig. 157, we have,

- Gear A with 30 teeth.
- Gear C with 65 teeth.
- Gear D with 20 teeth.
- Gear B with 40 teeth.

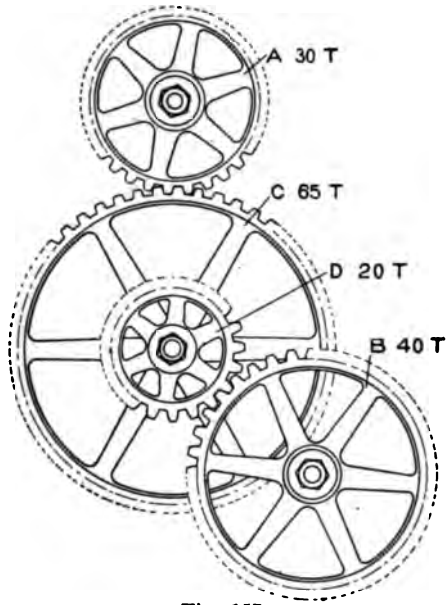


Fig. 157.

It is desired to cut a screw with 11 threads to the inch on a lathe having a lead screw with a pitch of $\frac{1}{4}$ inch. The gears available have 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, and 100 teeth respectively. What ones are to be used and where?

Ans.	{ Spindle	40 teeth
	{ Intermediate driven	55 teeth
	{ Intermediate driver	50 teeth
	{ Screw	100 teeth.

Many screw-cutting lathes are not made with an extension of the spindle to receive the first gear, but a short shaft or stud projects from the headstock for this purpose. This stud is geared to the spindle, and the ratio of this gearing must be considered when calculating the gears for screw-cutting. For example, suppose we wish to cut twelve threads per inch in a lathe having a lead screw with eight threads per inch and a ratio of two to one between the spindle and the stud. In other words, the stud runs half as fast as the spindle. As we have seen in the previous examples, the ratio between the spindle and the lead screw must be 12 to 8

The first gear is not attached to the spindle, but to the stud, which makes six revolutions to twelve of the spindle. Therefore, the ratio between the stud and the lead screw, where the gears are actually applied, must be 6 to 8. Multiplying by 6 will give 36 and 48 as the number of teeth in two gears which may be used.

In general, the data that must be given to calculate the change gears for screw-cutting are the number of threads per inch to be cut on the work, the number of threads per inch on the lead screw, and the speed ratio between the spindle and the stud, if a stud is used.

The following examples may be taken as applying to either right- or left-hand threads. The change of direction in the travel of the carriage is obtained by introducing an extra gear into the train, thus reversing the rotation of the lead screw.

The following description of the method of cutting a "V" thread will suffice to illustrate the cutting of any form, with the slight changes which are necessary in the other forms due to the shape of the tool employed.

To cut an ordinary V thread, a V-pointed tool having an angle of 60° , and set so that a line at right angles to the lathe axis bisects the tool angle, and also set exactly at the height of the center, is caused to move at a constant rate parallel to the work surface, while the work is being uniformly rotated.

The relation between the rotary motion of the work and the lateral movement of the tool, determines the pitch of the thread being cut, and the mechanism connecting the work and the tool must be of a positive character; thus eliminating transmission by belts and other frictional devices.

Owing to the lost motion or "back lash" in the mechanism connecting the tool and the work, the tool cannot be returned to the starting point for a new and deeper cut by simply reversing the lathe. The tool must be withdrawn, the lathe reversed, the tool returned to the starting point, and then advanced for the new cut. To place the tool for the new cut with accuracy, a stop or graduated device is provided.

If removed from the lathe for testing, care should be taken in replacing the work to get the tail of the dog in the same slot

in the face plate that was used to cut the original thread; this can be done by marking or otherwise indicating it.

Chasing. The ordinary methods of cutting screws have already been described. Where great accuracy is not necessary, the threads may be chased by hand. A chaser, or chasing tool, differs from the ordinary thread-cutting tool, in that it has a number of cutting points instead of but one. When a chaser is operated by a power feed, it is customary to have a shaft revolving at the same rate or at an even multiple of the rate of the lathe spindle. This shaft carries a master thread into which a section of a nut drops. The handle connected with the nut carries the chasing tool. When the nut is in contact, the tool is cutting. At the end of the cut, the tool is lifted out, and with it the nut disengages with the thread.

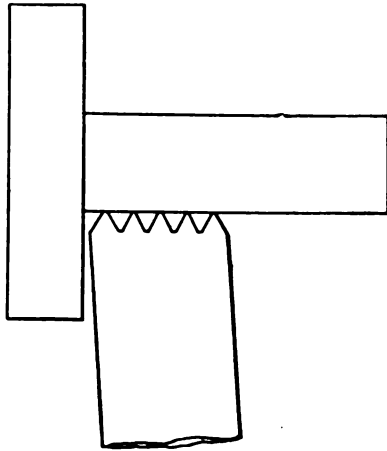


Fig. 158.

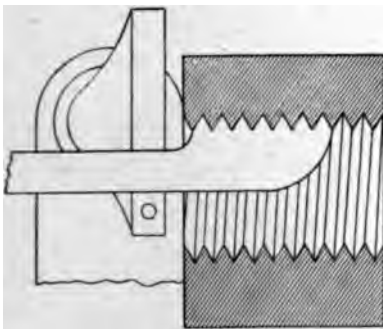


Fig. 159.

Hand-chasing requires a great deal of skill in order that a good piece of work may be done. The chasing tool has a number of points as shown in Fig. 158. The work must be run rapidly in the lathe. The tool is held in both hands, and is supported on a rest similar to that shown for the hand-turning tools in Fig. 86. The first left-hand tooth of the chaser is brought lightly against the right-

hand edge of the work. The handle is given a quick twist from left to right throwing the teeth in the opposite direction. It is well after the first twist, to stop the lathe and examine the

work. If the operation has been properly performed, the second tooth will be found to have entered the groove made by the first. A short length of thread will have been cut, the pitch being the same as that of the chaser. If this is correct, the lathe may again be started and the chaser applied as before. On the second trial the thread may be run to its full length. The finishing of the thread is done by merely repeating the operation. A fine cut is taken with each application of the chaser for the whole length of the thread until the full depth has been cut. In doing this work, the rear or right-hand side of the chaser should be pressed more firmly against the piece being cut than the front,

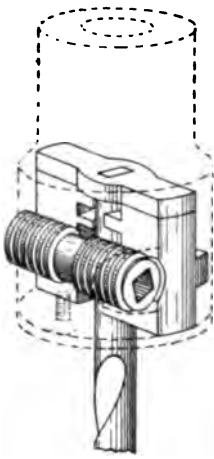


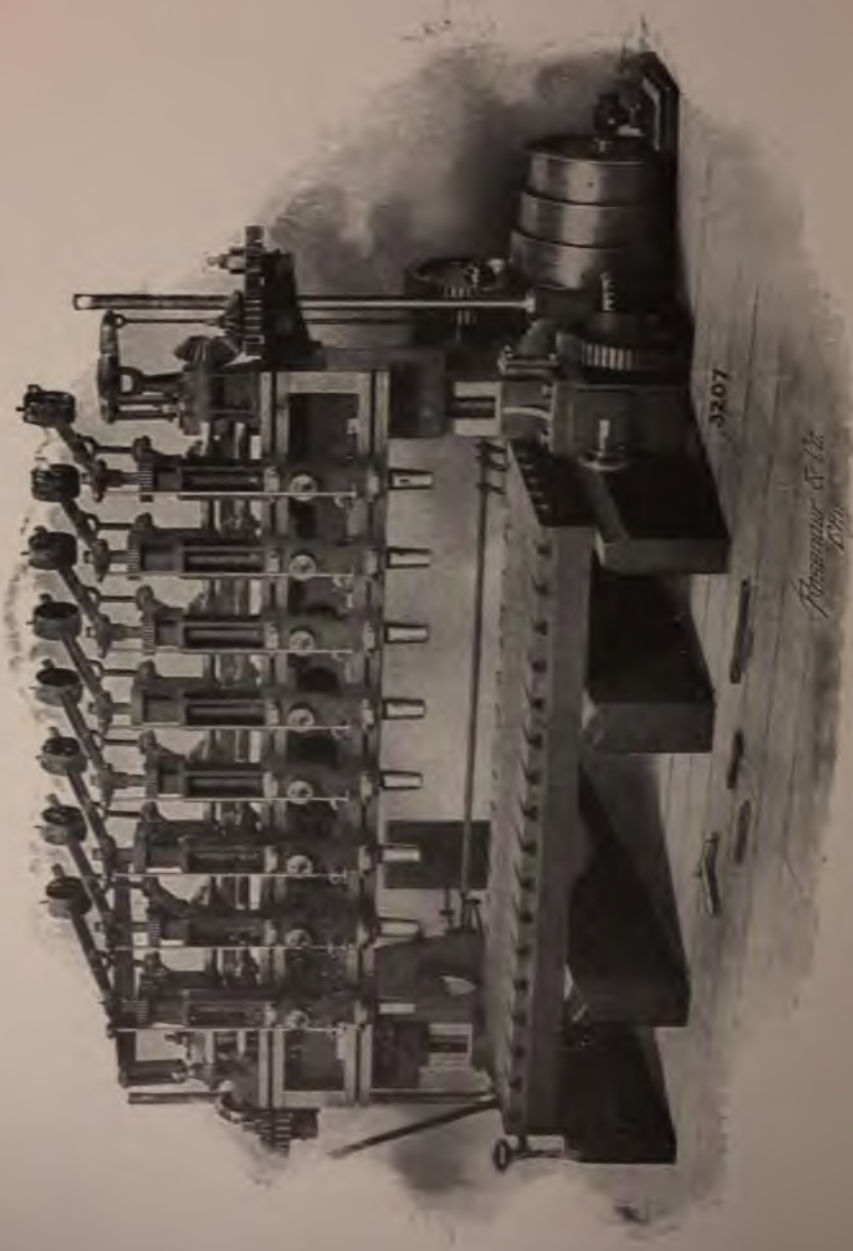
Fig. 160.

because the threads with which that portion of the tool is engaged are more deeply cut than at the front. In addition to cutting, these teeth also guide the front. The reason for running the lathe at a high rate of speed, is that the movement of the chaser is less likely to be checked or thrown aside by seams or inequalities in the density of the metal than it would be if the lathe were to run slowly. Inside threading may be done by means of the inside chaser shown in Fig. 159.

Drilling in the Lathe. The lathe can also be used for drilling. When such work is to be done, the drill may be held in the spindle and the work forced up against it by the screw of the tail stock: or the work may be revolved and the drill forced in by the tail-stock screw. When the first method is followed the drill may be put into a socket prepared for it in the spindle of the lathe, or the drill may be held by a drill chuck as shown in Fig. 160. This chuck may be used in the tail-stock to hold twist drills, or to hold flat drills which are forged from round stock. Flat drills made from flat stock are centered at the rear end and held against, and fed forward by, the dead center. In this case, a slotted rest held in the tool post prevents the drill from turning (see Fig. 60) and aids in starting the drill true.

When the drill is held in the head stock, the work may be

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MULTIPLE DRILLING MACHINE.

fastened to the carriage and fed against the drill, or it may be held by means of a suitable device held in the tail stock. For this purpose the drill pad, shown in Fig. 161, may be used, and especially if the work be flat. The V center, shown in Fig. 162, is

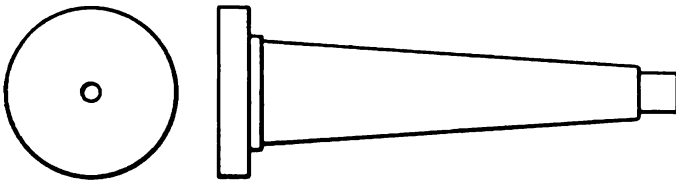


Fig. 161.

used when it is desired to drill through the axis of a piece of round stock. The shape of the groove prevents the work from turning and the angle being always in the axis of the lathe determines accurately the location of the hole.

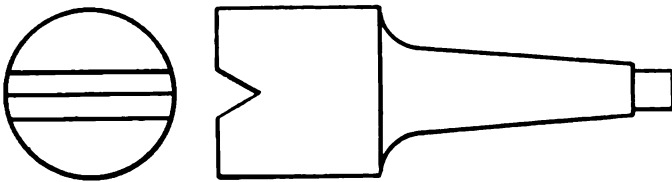


Fig. 162.

THE DRILL PRESS.

This tool is made in a great variety of forms, according to the class of work it is intended to perform. The form illustrated in Fig. 163 is one of the standard makes. The mechanism is very simple and will be briefly explained.

The frame consists of a strong column A, securely bolted to a heavy base-plate B. Power is delivered to the machine by means of a belt running over the cone pulley C. The shaft upon which this cone pulley turns, runs through the casing D, where, by means of miter gearing, it drives the vertical drill spindle E. It will be seen that there are four steps on the cone pulley C, thus affording a means for securing as many rates of revolution of the drill spindle. This, however, is not sufficient to meet all the

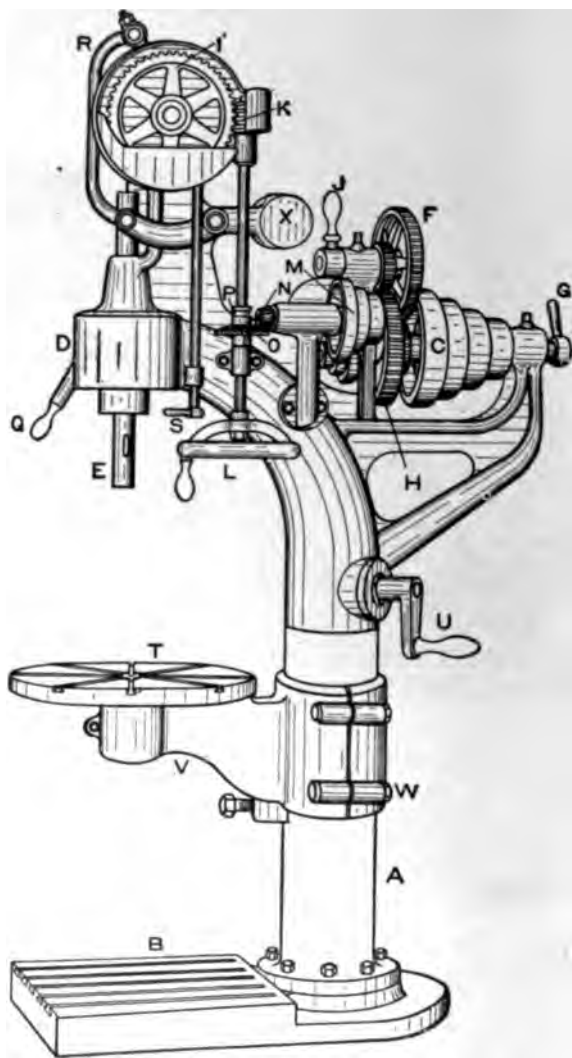


Fig. 162.

requirements of the work that can be done with the tool. In order to increase the range of available speeds, a *back gear* is used. This is shown at F. It consists of a gear and pinion keyed to the same shaft. The cone pulley C is loose on the horizontal shaft, but may be fastened to it by a clutch operated by the lever G. The inner end of the cone pulley carries a pinion that meshes with the gear F, while the pinion attached to F meshes with the gear H that is keyed to the horizontal shaft. The gear F and its pinion run loosely on a journal that is, in turn, attached to an eccentric bearing. By turning the handle J, which is attached to the eccentric bearing, the gears may be thrown in or out of mesh. While the gears are in mesh, the power passes from the cone pulley to the pinion attached to it, to the gear F, to its pinion, and thence to the gear H, and thus turns the shaft. Under these circumstances the shaft is turning much slower than the cone pulley.

The feed, or downward motion of the drill spindle may be accomplished by hand or by power. At the upper end of the drill spindle a rack is cut, into which a pinion on the same shaft as the worm wheel I meshes. It is evident that, as this wheel revolves, the spindle will be raised or lowered.

The weight of the spindle is counterbalanced by the weight X. The worm wheel I is turned by the worm K, which is rotated by the hand wheel L. This serves for a hand feed. For a power feed, a belt is made to drive the cone wheel M. This turns the bevel pinion N, meshing with the bevel gear O, that is loose on the feed shaft. It is fastened to the latter by means of a small clutch P. A quick return of the spindle is accomplished by means of the handle Q. This is attached to the spindle by means of a yoke R. When the quick return is to be used, the worm K is thrown out of mesh with its wheel by turning the handle S.

The table T may be raised or lowered by means of the handle U; this drives a screw in the standard running in a nut fastened to the bracket V. When the table has been adjusted, it may be fastened by the nuts and bolts W clamping it to the standard A. When large work is to be drilled, the table may be swung out of the way and the work bolted to the base plate B.

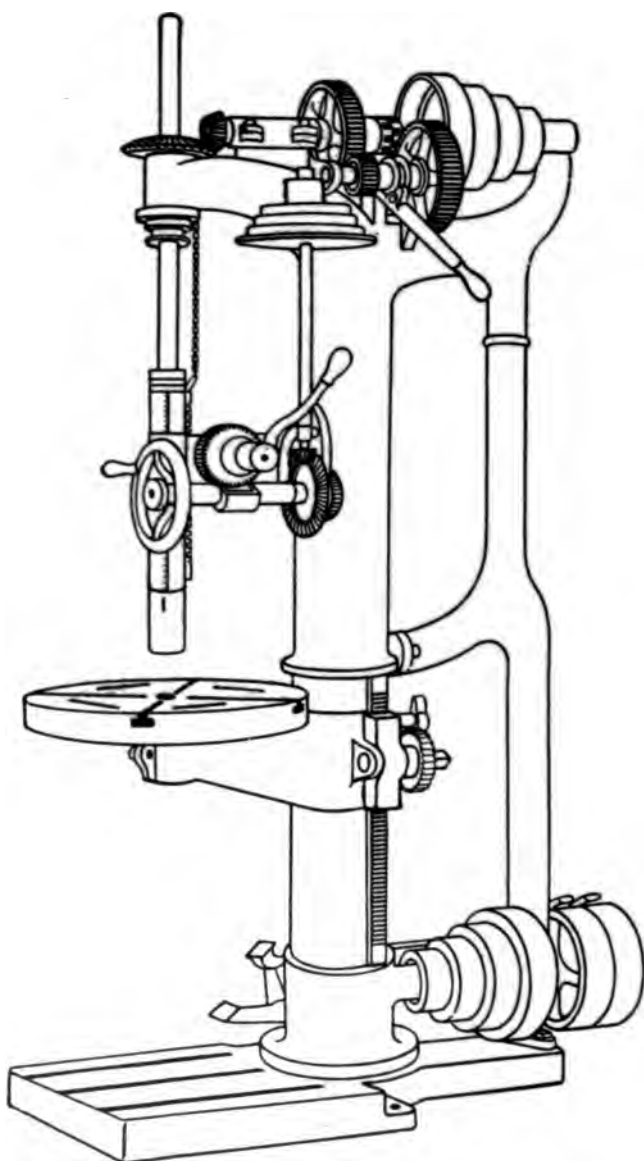


Fig. 164.

While the drill press just described may be taken as representing good practice in the smaller sizes, a different form of construction is often employed in larger tools. A drill press of this class is shown in Fig. 164. Drilling machinery is made both horizontal and vertical. A typical form of the horizontal variety is shown in Fig. 165. These tools are usually of heavier construction and for a larger class of work than the ordinary vertical drill.

Drilling machinery, both horizontal and vertical, is sometimes provided with more than one spindle. In small vertical drills of this description, the spindles are fixed in their relative

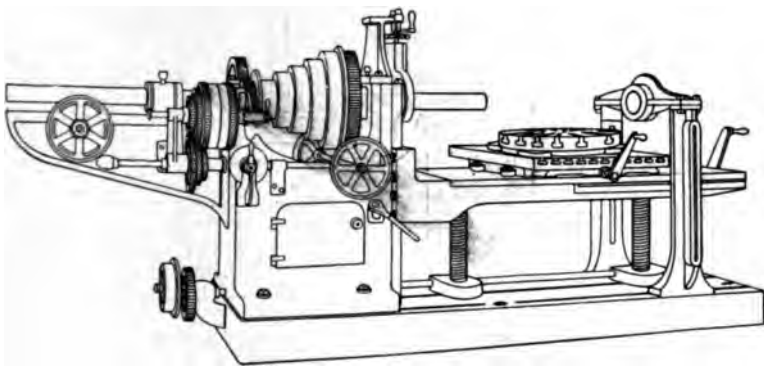


Fig. 165.

positions and are not intended to be operated simultaneously; the work is passed from one spindle to another. The true multi-spindle drill is for the purpose of drilling several holes at one time and in any relative position within the limits of adjustment of the machine. Such a drill is shown in Fig. 166.

The Radial Drill. Another form of drill, known as the radial, is being extensively used. It is shown in Fig. 167.

The drill spindle is carried on the arm A. It is so arranged that it can be set and run at any position on this arm. At the same time, the arm may be swung around and clamped in any vertical or horizontal position about the upright B. These drills are usually employed on heavy work, where a number of holes are to be drilled.

In the case of the drill shown in Fig. 163, the work is

ordinarily light, and can be readily shifted so that the position of the holes can be brought beneath the drill. In heavy work, such as engine cylinders, however, this cannot be done. It is, therefore, necessary to be able to shift the drill and place it in a position to do the work. The radial drill affords the means of doing

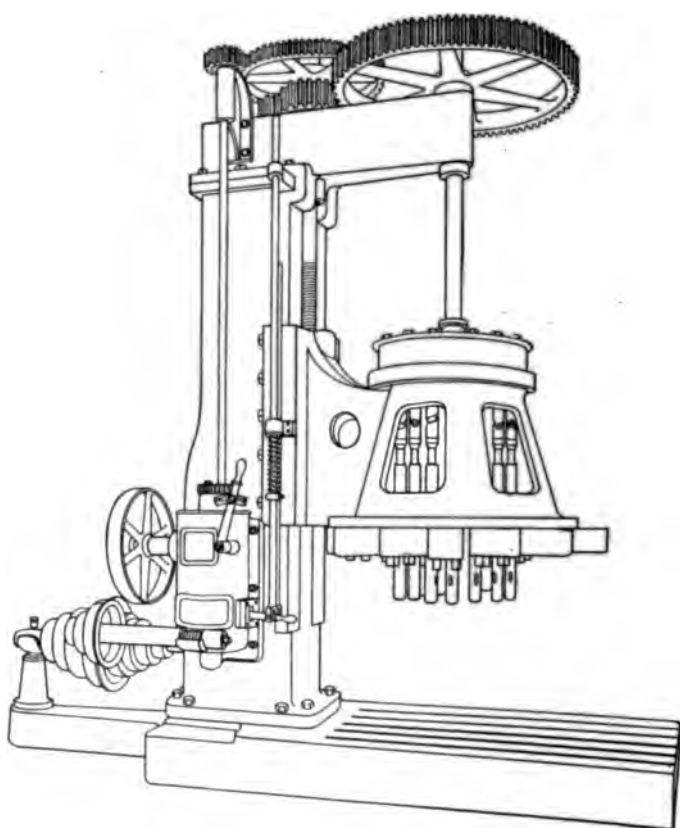


Fig. 166.

this. When the vertical spindle carrying the drill can be rotated in the vertical plane, holes can be drilled, not only in any position, but also at any angle. Such a drill is called a Universal Radial.

The position of the holes is usually laid out for the guidance of the man at the drill. The work is best done as shown in Fig. 168. The center punch mark, indicated by A, shows the

location of the center of the hole. The circle upon which the prick punch marks BBBB are placed, gives the location of the circumference of the hole. To drill the hole, place the point of the drill in the center punch mark A, and drill into the metal until the center punch mark has been slightly enlarged, as shown by the circle C, Fig. 168. Then raise the drill and examine the work. If the countersink or hole, whose circumference is indi-

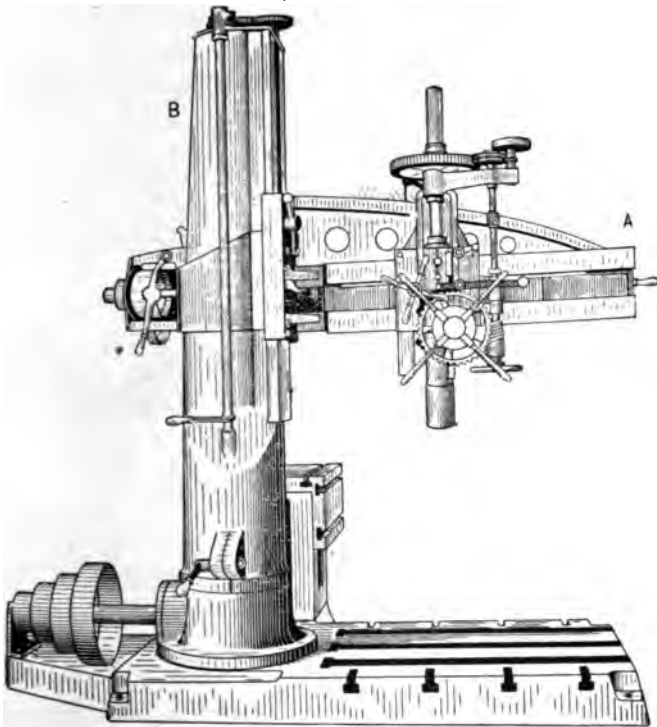


Fig. 167.

cated by the circle C, is exactly concentric with the outer circle BBBB, then the drill may be put down and the hole drilled.

Owing, however, to various causes, it is not often that the circle will be concentric. This may be due to an uneven grinding of the drill, a distortion of the metal by the center punch, or an eccentric motion of the drill point, due to a lack of truth in the running of the spindle.

When the countersink is not concentric, the drill must be drawn back to the central position. The method employed is shown in Fig. 169. The round-nosed chisel is used to cut a groove, E, down the side of the countersink, on the side that is farthest from the circle BBBB. The depth of this groove depends upon the amount of eccentricity of the countersink and the depth to which it has been drilled. The drill is then run down again and the groove drilled out. The action of this groove is as follows: as the drill turns, one cutting edge is supported, and is working into the face C, Fig. 170. At the same time the cutting edge is opposite the groove E. The drill, therefore, springs into

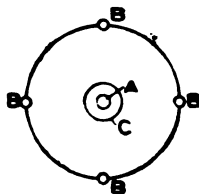


Fig. 168.

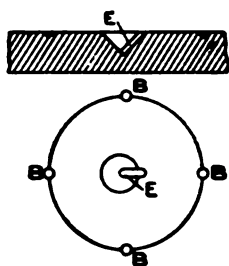


Fig. 169.

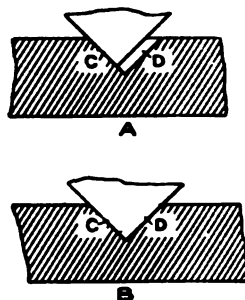


Fig. 170.

the groove, as shown. The lip then catches on the edge of the groove and cuts it away, making the hole elliptical, and shifting the center of the drill towards its proper position. As the drill sinks deeper both lips are in contact with the faces C and D, and it has no further tendency to shift.

When the groove has been drilled out, the drill must be again raised, to ascertain whether or not the countersink is concentric with the outer circle BBBB. If not, another groove must be cut, and the process repeated. If it is, the hole may be drilled. The prick punch marks BBBB are put on the outer circle to indicate its position in case of the obliteration of the line itself.

A twist drill will usually clear its hole of chips. For deep holes this may not occur. It is then necessary to withdraw the drill and clean out the hole. This can be done by a piece of wire bent at the end; also by using a "blowpipe" made of a small tube, and bent to enter the hole, so that the chips will not blow

up into the operator's face. Cast iron is more likely to need cleaning than wrought iron or steel. Where flat drills are used, it is always necessary to clean the holes at frequent intervals, as they have no tendency to raise the chips and clear the holes.

A matter to receive due consideration is that the work must be held rigidly on the table while being drilled. This may be done in two ways. If the holes are to be drilled with great accuracy, the work must be clamped to the table. This is often done by means of straps, as shown in Fig. 171. In this figure, a gland A is shown clamped to the table by the straps BB. One end of the strap rests upon the flange of the gland, and the other upon any convenient piece of metal C, of the proper thickness. The bolt D is put up through a hole in the table as close to the

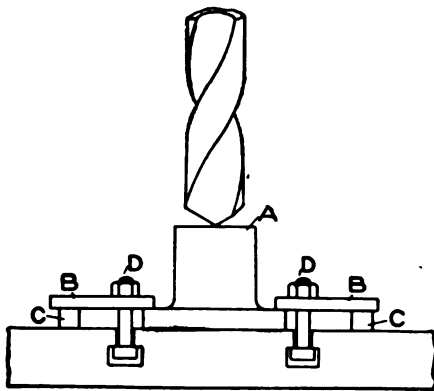


Fig. 171

work as possible. When the nuts are screwed down, they then put the greatest available pressure on the work and hold it fast. The strap B is made of flat iron. It has one or more holes drilled in it to permit the passage of bolts.

Another method of holding work in the drill press is by means of a post. This is shown in Fig. 172. It consists of a post A, set loosely in one of the holes in the table. As the drill is forced against the work, it tends to turn the latter with it. When the work strikes the post, it is stopped and held while the hole is drilled. This will not hold the work perfectly steady. It allows the latter to move with the eccentricity of the motion

of the drill, but it is in very common use where extreme accuracy is not essential. For example, where a finished bolt is to be used with a driving fit, the work must be securely fastened so that the diameter of the hole may be true. Where a machine bolt made of rough iron is to be used, the hole is drilled $\frac{1}{16}$ inch larger than the normal size of the bolt. Here accuracy is not

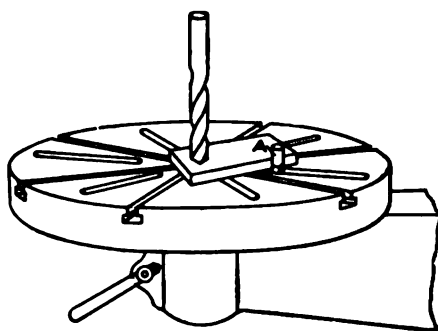


Fig. 172.

even attempted; a variation of $\frac{1}{32}$ inch in the diameter of the hole is of no account. Therefore, in such cases, the work may be allowed to merely rest against the post.

This question of holding the work does not apply to drills of the multi-spindle class. It is evident that the tendency of one drill to rotate the work is *counteracted by the action of another drill*. Therefore, no holding devices are needed on drills of more than one spindle.

An angle iron, forming a right angle with the drill table, is used in many cases where the hole cannot be properly located by the use of the table alone. The clamping to the angle iron must be very rigid to resist the pressure of the drill. A tilting table is sometimes used so that holes may be drilled at any required angle. At least one manufacturer is putting on the market a horizontal drilling machine which can drill five sides of a cube at any angle with but one setting of the work.

Drilling machines may also be used for tapping. This requires a reversing device for backing out the tap. The backing-out is done at a much higher speed than the tapping. The tap is held in a friction head that will slip when the tap strikes the bot-

tom of the hole. The use of collapsing taps, especially on diameters of one inch and over, renders the backing-out unnecessary and quickens the operation. Studs may be set by the same device, so that cylinder flanges may be drilled, tapped, and the studs set without removing the work from the drill. Duplicate drilling by means of jigs will be considered later.

THE PLANER.

Next to the lathe, the planer is the most important tool in the machine shop. As the name indicates, it is used for finishing flat surfaces. In the ordinary planer, the work is moved and the tool is at rest. A common form of this tool is shown in Fig. 173. It consists of a bed A upon the upper surface of which suitable guides or ways are planed. The platen B is made to travel back and forth upon these ways. The platen has a rack on its under surface into which the gear C meshes. This gear is driven by a train of gears from the shaft carrying the pulley D. The tool is carried on the tool-head E, where it can be given a slight vertical motion or feed. This tool-head may be fed across the machine by the screw in the cross-rail F. The latter may be raised and lowered by the shaft and gearing shown at the top. This gearing turns two vertical screws running in nuts attached to the cross-rail.

The reciprocating motion of the platen is obtained as follows: the pulleys D and G are driven in opposite direction by belts. Either one may be connected to the shaft on which they turn by a clutch which is operated by the bell crank lever J. On the platen there are two adjustable dogs IIII. These are set so that, when the work has just cleared the tool in either direction, one of them will strike against the upper end of the lever I. In the illustration, if the platen is moving in toward the right-hand dog, II will have struck the lever. As the platen continues to move, the lever I is carried to the right and the clutch connection fastening the forward pulley to the shaft broken and that of the return made. The motion is then reversed and continues until the left-hand dog strikes the lever I and again changes the motion.

Ordinarily the tool cuts only when the platen is moving toward the right Fig. 173. As a result of this condition, the

platen is made to move more rapidly in the direction of the arrow than in the reverse. This is accomplished by varying the speeds of the pulleys D and G. The usual ratio of the speeds of these pulleys is from 1 to 2, to 1 to 5.

The feed of the tool is accomplished by a friction clutch driving the vertical rack K. This acts only at a point near the

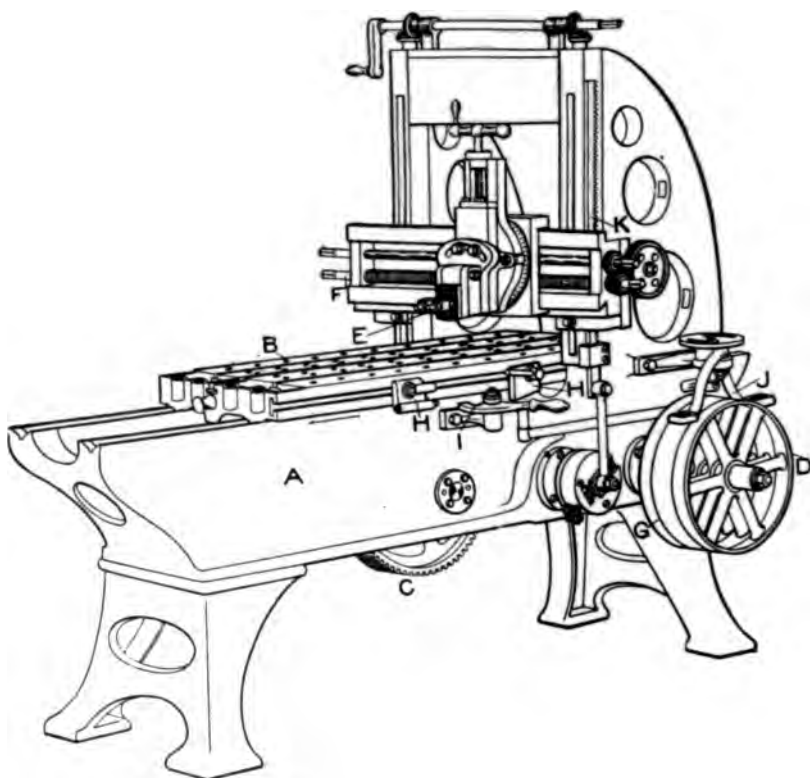
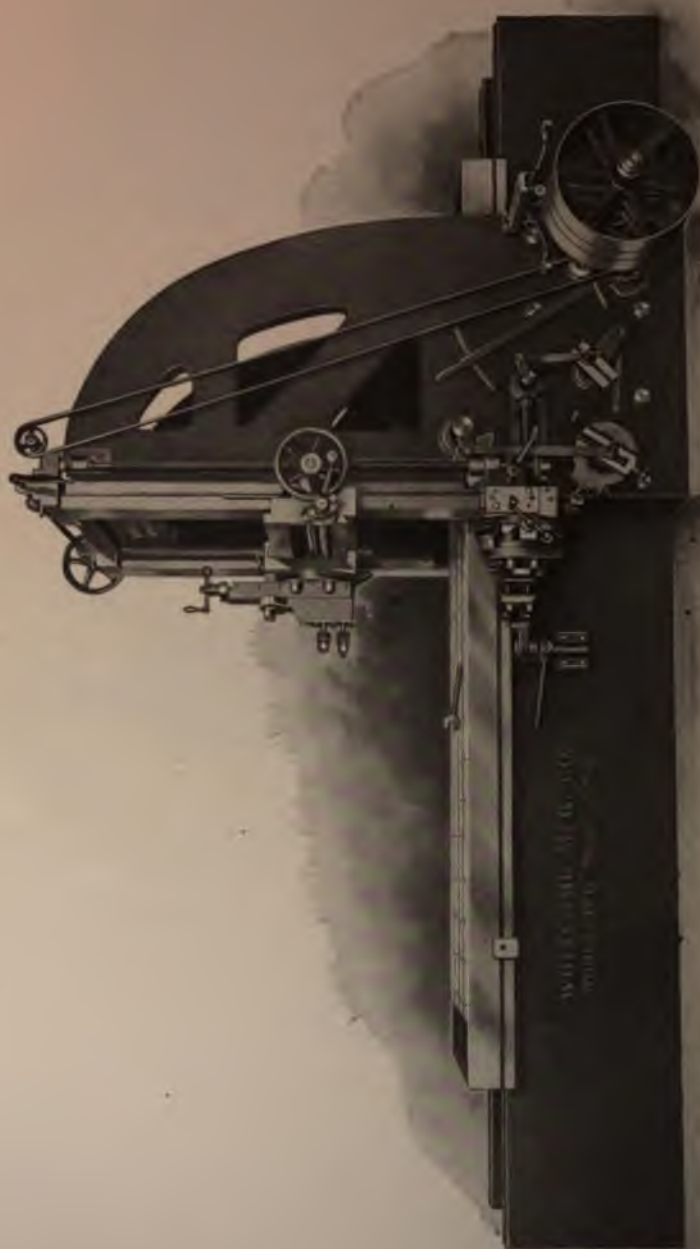


Fig. 173.

end of the travel of the platen. It is so arranged that any vertical or horizontal feed may be given to the tool.

Planers are made in a great variety of sizes and styles. Very frequently there are three driving pulleys placed side by side on the same shaft, the central one of the three keyed to the





36' x 36" x 10' PLANER.
Whitcomb Manufacturing Co.

shaft. The reversal of the motion of the platen is obtained by shifting one or the other of the belts onto the central pulley.

Planer Tools. The tools that are used upon planers do not differ essentially from those described for lathe work. The same rule applies regarding the holding of the tool. It should project as short a distance as possible beyond the point of support.

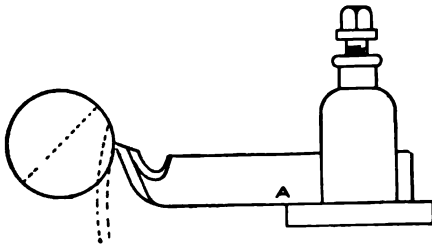


Fig. 174.

When there is an excessive projection, care should be taken that the tool is so set that it will not spring into the work. On the lathe this can be prevented by setting the point of the tool on a line with the center. In Fig. 174 the tool tends to spring and turn about the point A as a center. The dotted line at the point shows how this tends to throw it into the work. The same thing is shown in the planer tool in Fig. 175. This tendency can be overcome by forging the tool so that the cutting point is behind a perpendicular from the point of support, as shown by the dotted lines in Fig. 175. In the latter case the spring of the tool tends to take it out of the work.

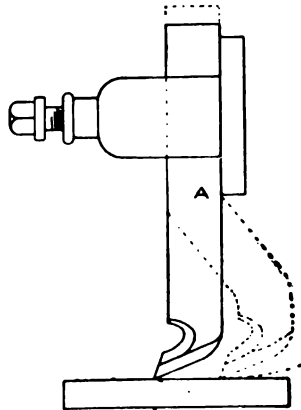


Fig. 175.

Holding the Work. The work is usually held on the planer by clamping it down with straps in a manner similar to that shown in Fig. 171. Where the whole upper surface is to be planed over, holes are sometimes drilled in the sides, into which the rounded ends of straps are set.

It is impossible to give more than general directions for clamping work on a planer. A great variety of blocking, clamps and bolts must be used; such attachments being suited to the work in hand, and requiring an outlay of money which seems to be out of proportion to the appearance of the collection. It

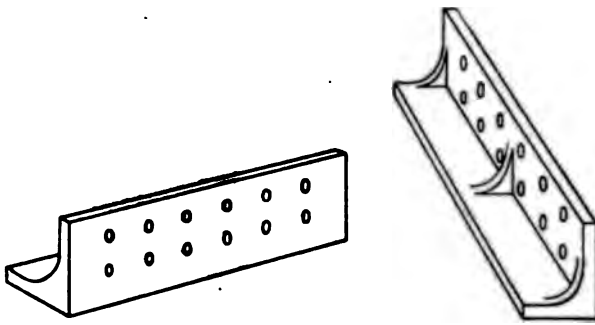


Fig. 176.

should be sufficient to say that the work must be carefully set, strongly clamped and braced to prevent movement by the tool; the clamping should not distort the work. As all castings and forgings change their shape when the surface is removed, it is considered good practice to release the clamps before the finishing

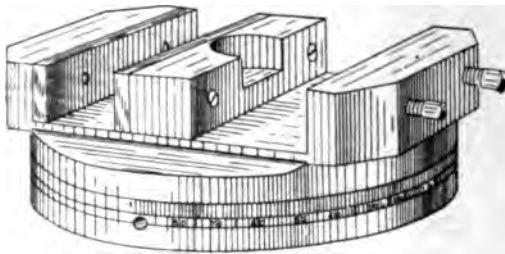


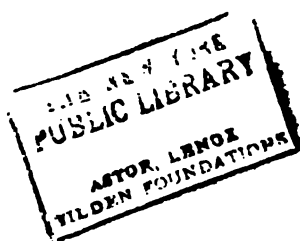
Fig. 177.

cut, in order that the piece may assume its final shape, and then reclamp it without distortion.

Angle irons or knees, as shown in Fig. 176, may be considered as an auxiliary table with a surface at right angles to



TRAVERSE SHAPER.
The Cincinnati Shaper Company.



main table. Many useful applications of these holding devices will suggest themselves.

Another method of holding work is by using a vise such as is shown in Fig. 177. The body is bolted to the platen and the work is held between the jaws.

Planer centers, as illustrated in Fig. 178, are very useful in machining parts where accurate circular spacing is desired, or where projecting lugs prevent turning in the lathe.

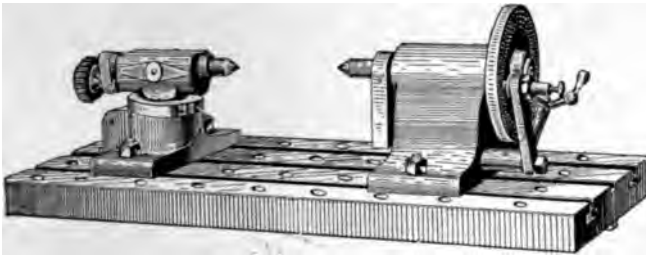


Fig. 178.

The Plate Planer. A special form of planer extensively used in boiler shops and shipyards is the plate planer, Fig. 179. It is used for planing the edges of long plates. The plate is securely fastened between the clamps A and the bed B. The tool is held in the carriage C, which is moved to and fro by the screw D. The screw is driven by the gear H, that meshes with a pinion keyed on the shaft to which the motor is geared. The reversal of motion is obtained by shifting the clutch K. The tappets M for moving the shifting gear are upon the shaft I. They are struck as the carriage approaches the end of its stroke. Unlike the ordinary machine shop planer, the plate planer has no quick return stroke, but has a tilting tool which allows stock to be removed when moving in either direction. Devices of this character have often been tried on regular metal planers, but seem to be satisfactory only when the whole face of the work can be covered at a single stroke of the tool.

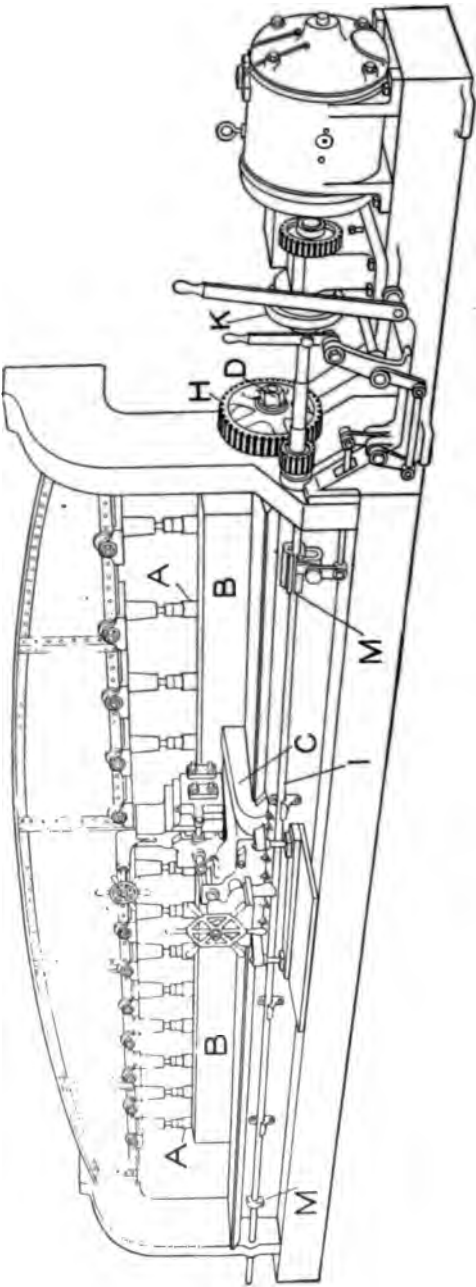


Fig. 178

THE SHAPER.

For light work the shaper or shaping planer, Fig. 180, is extensively used. It possesses the advantage of rapidity of action. In this machine, as in the plate planer, the tool moves while the

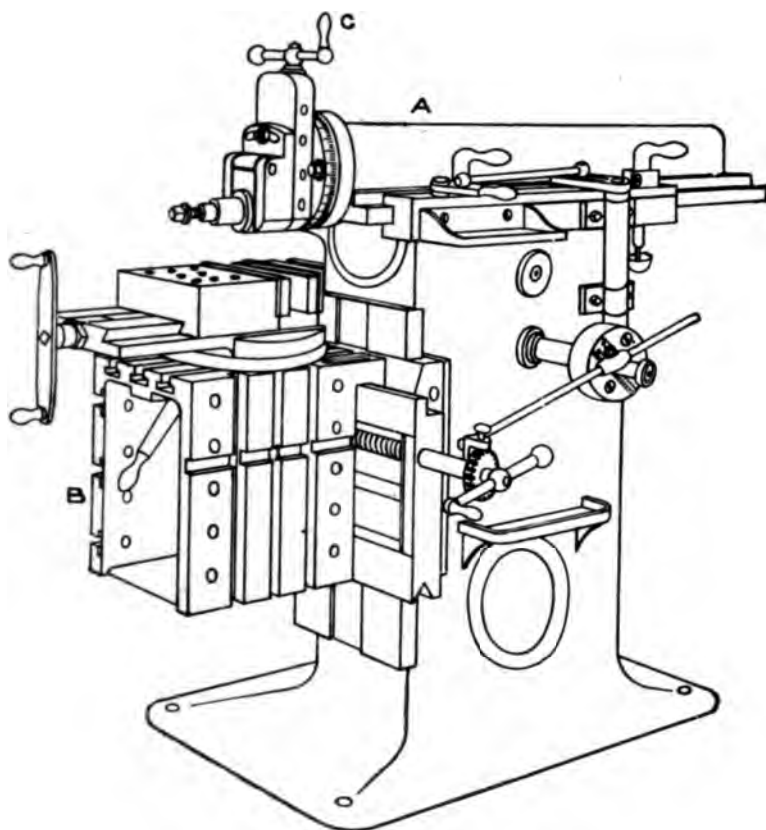


Fig. 180.

work is at rest. A suitable mechanism causes the ram A to move back and fro. When moving toward the left, the tool is cutting. As in the ordinary planer, the cutting speed is less than the return.

The work is held on the table B, which may be adjusted to any convenient height suited to the work to be done. The tool is also allowed a limited vertical adjustment in the slide by turn-

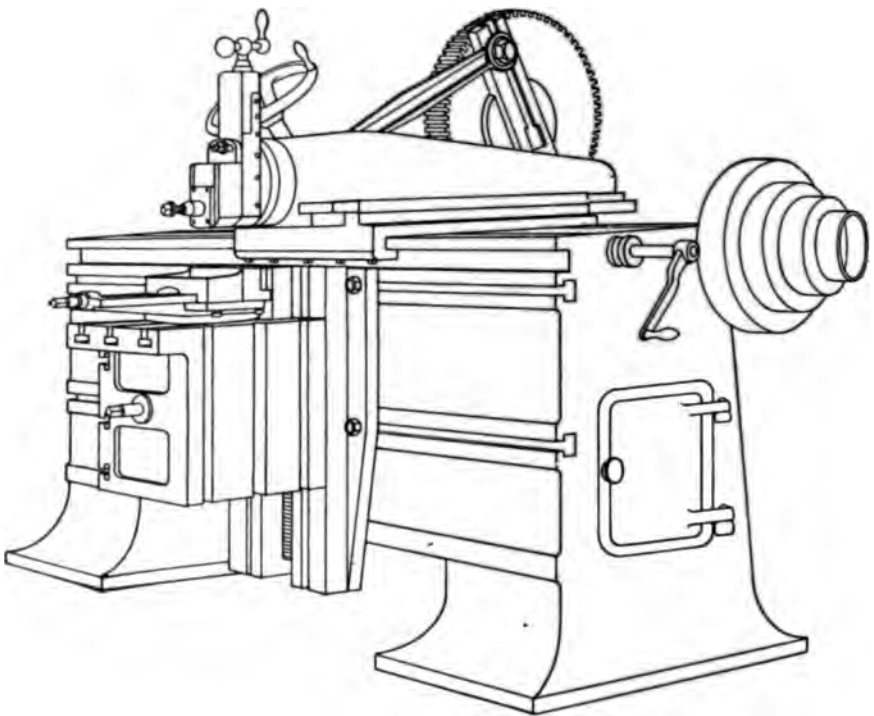


Fig. 181.

ing the handle C. This is the ordinary method of obtaining the vertical feed.

The horizontal feed is obtained by moving the table B sidewise. In some shapers it can also be moved vertically to feed to or from the tool; in others the horizontal feed is obtained by causing the tool with the reciprocating parts to move sidewise.

The style of machine shown at Fig. 180 is called the pillar shaper, but where the tool and ram move sidewise it is called the

traverse shaper; see Fig. 181. The character of the work done on the shaper and the planer is identical, but as a rule, the shaper is used for the smaller and more delicate parts which could not be handled quickly on the planer. The shaper has the additional advantage of a change of speed which allows small pieces, especially of the softer metals, to be machined at a maximum rate.

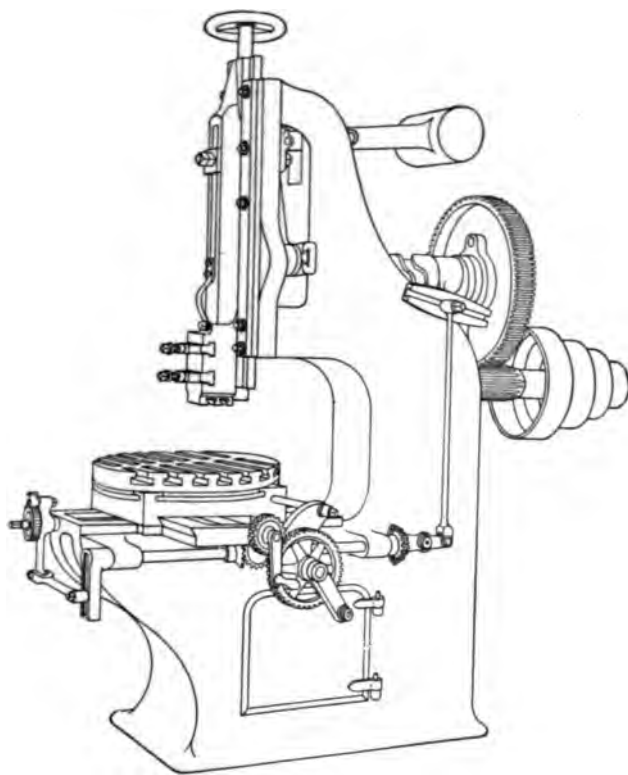


Fig. 182.

Slotter. Another machine tool which is not used as commonly as its many good qualities would seem to warrant is the slotter, Fig. 182. It is, in reality, a shaper with the tool moving vertically instead of horizontally. It is used for working on heavy pieces, and especially in places where an irregular contour is to be formed. The thrust on the tool is vertical, and it must

be very stiff. The work done frequently partakes of the nature of the forming of the inside of the hole where the tool must project the whole length of the cut below the bottom of the head.

Such a case is that of the slotting of locomotive frames. The best type of tool for such a class of work is a strong bar, as shown in Fig. 183. The bar is held in the head of the tool just as any tool would be. Near the lower end it carries the cutting tool, which may be fastened by a set-screw or wedge. Such a tool should always be used when it is possible. It has the advantage of being stiffer and less likely to spring than a forged tool.

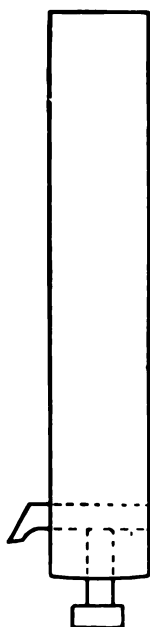


Fig. 183.

The tool used in a slotting machine differs from that used in the lathe or planer in that the direction of the cutting motion is different. Fig. 184 illustrates a slotting tool to be used for doing such work as the cutting of keyways in the hubs of pulleys. It will be seen that if the tool is moved in the direction of the arrow, the face B becomes the one against which the chip bears. It, therefore, corresponds to the top of the lathe tool. The sharper the slope given to the face B, the keener the edge, just as increasing the rake of the lathe tool increases its sharpness. The face A must also be cut away as indicated. This corresponds to the



Fig. 184.

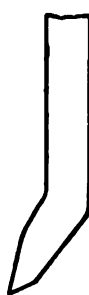
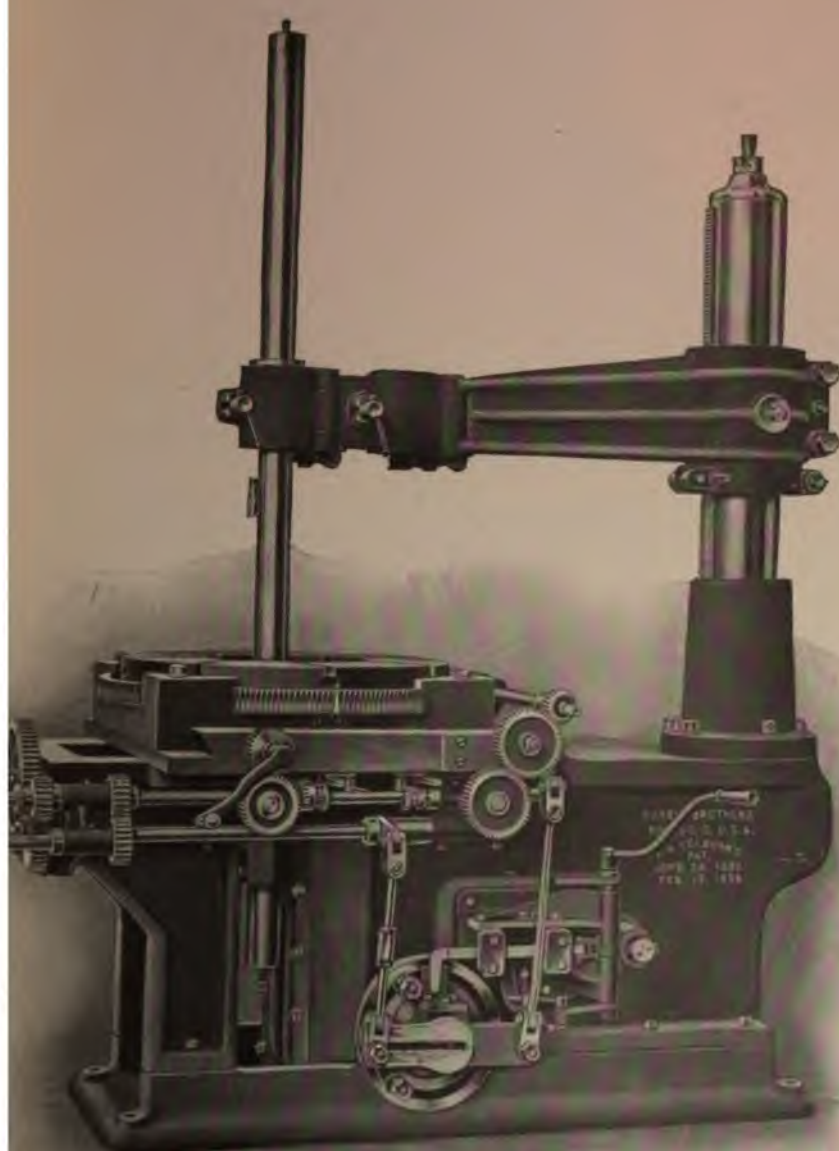


Fig. 185.

clearance of the lathe or planer tool. It is quite possible, at times, to give these tools a larger amount of rake. Such a form

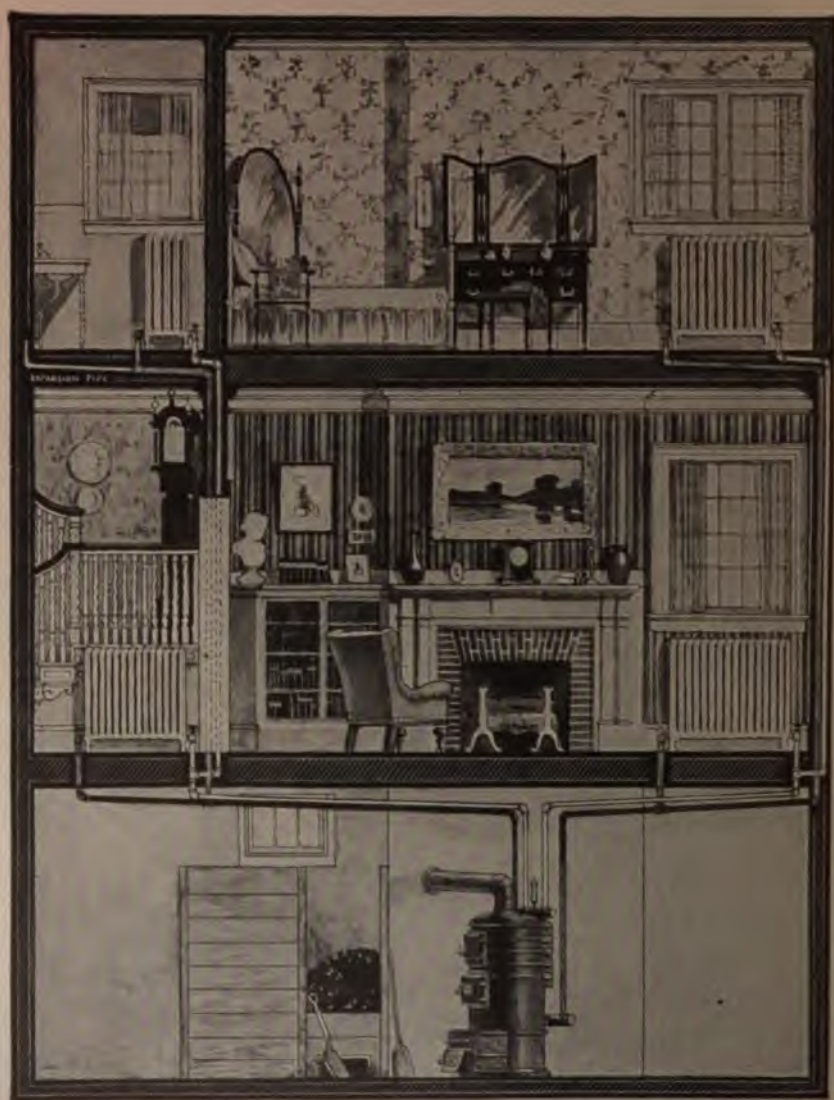


DRAW STROKE SLOTTER.
Baker Brothers.

MACHINE SHOP WORK.

is shown in Fig. 185. The shape of this tool is such that it is very strong in the direction of the thrust, besides having a keen cutting edge.





HOT WATER HEATER AND CONNECTIONS.

HEATING AND VENTILATION.

PART I.

SYSTEMS OF WARMING.

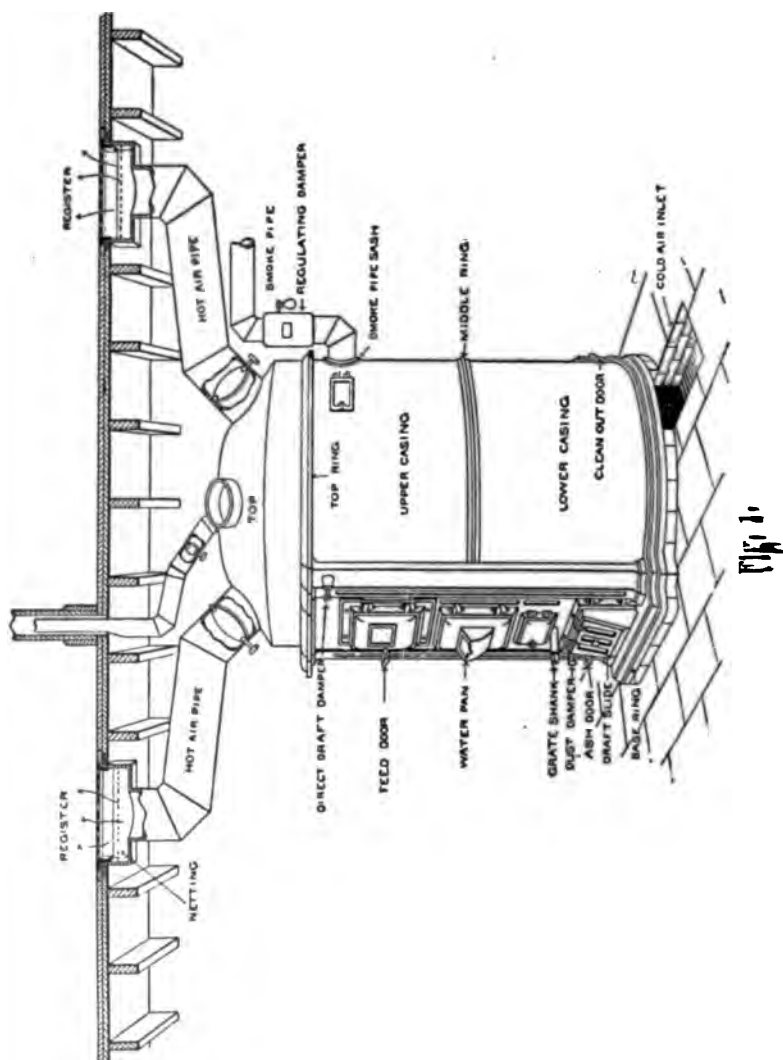
Any system of warming must include, *first*, the combustion of fuel which may take place in a fireplace, stove, steam or hot-water boiler ; *second*, a system of transmission, by means of which the heat may be carried, with as little loss as possible, to the place where it is to be used for warming, and *third*, a system of diffusion, which will convey the heat to the air in a room and to its walls, floors, etc., in the most economical way.

Stoves. The simplest and cheapest form of heating is the stove. The heat is diffused by radiation and convection directly to the objects and air in the room, and no special system of transmission is required. The stove is used largely in the country and is especially adapted to the warming of small dwelling houses and isolated rooms.

Furnaces. Next in cost of installation and simplicity of operation is the hot-air furnace. In this method, the air is drawn over heated surfaces and then transmitted through pipes, while at a high temperature, to the rooms where heat is required. Furnaces are used largely for warming dwelling houses, also churches, halls and schoolhouses of small size. They are more costly than stoves, but have some advantages over that form of heating. They require less care, as several rooms may be warmed from a single furnace ; and, being placed in the basement all dust from coal and ashes is kept from the rooms above.

In construction a furnace is a large stove with a combustion chamber of ample size over the fire ; the whole being enclosed in a casing of sheet iron or brick. The bottom of the casing is provided with a cold-air inlet, and at the top are pipes which connect with registers placed in the various rooms to be heated. Cold fresh air is brought from out of doors through a pipe or duct called the "cold-air box ;" this air enters the space between the casing and the furnace near the bottom and in passing over the

hot surfaces of the fire pot and combustion chamber, becomes heated. It then rises through the warm-air pipes at the top of the casing and is discharged through the registers into the rooms above.



As the warm air is taken from the top of the furnace, cold air flows in through the cold-air box to take its place. The air for heating the rooms does not enter the combustion chamber.

Fig. 1 shows the general arrangement of a furnace with its connecting pipes. The cold-air inlet is seen at the bottom and the hot-air pipes at the top; these are all provided with dampers for shutting off or regulating the amount of air flowing through them. The feed or fire door is shown at the front and the ash door beneath it; a water pan is placed inside the casing and furnishes moisture to the warm air before passing into the rooms; water is either poured into the pan through an opening in the front, provided for this purpose, or is supplied automatically through a pipe.

The fire is regulated by means of a draft slide in the ash door and a cold-air or regulating damper placed in the smoke-pipe. Clean-out doors are placed at different points in the casing for the removal of ashes and soot. Furnaces are made either of cast iron, or of wrought iron plates riveted together and provided with brick-lined fire pots.

One great advantage in this method of warming comes from the constant supply of fresh air which is required to bring the heat into the rooms. While this is greatly to be desired from a sanitary standpoint it requires a larger amount of fuel than would otherwise be necessary, for heat is required to warm the fresh air from out of doors up to the temperature of the rooms, in addition to that lost by leakage through walls and windows.

A more even temperature may be maintained in this way than by the use of stoves, owing to the greater depth and size of the fire, which causes it to be more easily controlled. When a building is placed in an exposed location, difficulty may be experienced at times in warming certain rooms, depending upon the direction of the wind; this may be overcome to a large extent by a proper location of the furnace and the exercise of suitable care



Fig. 2.

in running the connecting pipes. This will be taken up later in the design of heating systems.

Direct Steam Heating. Direct steam heating is used in all classes of buildings, both by itself and in combination with other systems. The first cost of installation is greater than for furnace heating but the amount of fuel required is less, as no outside air-supply is necessary. If used for warming hospitals, schoolhouses or other buildings where ventilation is desired, it must be supplemented by some other means for providing warm fresh air. A



Fig. 3.

system of direct steam heating consists of a furnace and boiler for the combustion of fuel and the generation of steam; a system of pipes for conveying the steam to the radiators and for returning the water of condensation to the boiler; and radiators or coils placed in the rooms for diffusing the heat.

Various types of boilers are used, depending upon the size and kind of building to be warmed. Some form of cast iron sectional boiler is commonly used for dwelling houses, while the tubular or water-tube boiler is more usually employed in larger buildings. Where the boiler is used for heating purposes only, a low steam pressure of from 2 to 10 pounds is carried and the condensation flows back by gravity to the boiler which is placed below the lowest radiator. When, for any reason, a higher pressure is required, the steam for the heating system is made to pass through a reducing valve and the condensation is returned to the boiler by means of a pump or return trap. The methods of

making the pipe connections between the boiler and radiators vary for different conditions and in different systems of heating. These will be taken up later under the head of design.

Direct radiating surface is made up in different ways: Fig 2 shows a common form of cast iron sectional radiator; these can be made up in any size depending upon the height and number of sections used. Fig. 3 is made up of vertical wrought iron pipes screwed into a cast iron base and is a very efficient form. Fig. 4 shows a type of cast iron wall radiator which is often used where it is desired to keep the floor free from obstruction. Fig. 5 is a special form of dining-room radiator provided with a warming closet. Wall and ceiling coils of wrought iron pipe are often used



Fig. 4.

in school rooms, halls and shops or where the appearance is not objectionable.

Indirect Steam. This system of heating combines the advantages of both the furnace and direct steam but is more expensive to install. The amount of fuel required is about the same as in the case of furnace heating. Instead of placing the radiators in the rooms, a special form of heater is placed beneath the floor and encased in galvanized iron or brickwork. A cold-air box is connected with the space beneath the heater and warm-air pipes at the top are connected with registers in the floors or walls as

HEATING AND VENTILATION.

already described for furnaces. A separate heater may be provided for each register if the rooms are large, or two or more registers may be connected with the same heater if the horizontal runs of pipe are short. Fig. 6 shows a section through a heater arranged for introducing hot air into a room through a floor register and Fig. 7 shows the same type of heater connected with a



Fig. 5.

wall register. The cold-air box is seen at the bottom of the casing, and the air in passing through the spaces between the sections of the heater, becomes warmed and rises to the rooms above.

Different forms of indirect heaters are shown in Figs.

8 and 9. Several sections connected in a single group are called a "Stack." Sometimes the stacks are encased in brickwork built up from the basement floor instead of galvanized iron as shown in the cuts. This method of heating provides fresh air for ventilation, and for this reason is especially adapted for school-houses, hospitals, churches, etc. As compared with furnace heating it has the advantage of being less affected by outside wind pressure, as long runs of horizontal pipe are avoided and the heaters can be placed near the registers. In a large building where several furnaces would be required, a single boiler can be used and the number of stacks increased to suit the existing conditions, the



Fig. 6.

making it necessary to run but a single fire. Another advantage is the large ratio between the heating and grate surface as compared with a furnace, and as a result a large quantity of air is warmed to a moderate temperature in place of a smaller quantity heated to a much higher temperature. This gives a more agreeable quality to the air and renders it less dry. Direct and indirect systems are often combined, thus providing the living rooms with ventilation while the hallways, corridors, etc., have only direct radiators for warming.

Direct-Indirect Radiators.

A direct-indirect radiator is similar in form to a direct radiator and is placed in a room in the same manner. Fig. 10 shows the general form of this type of radiator and Fig. 11 shows a section

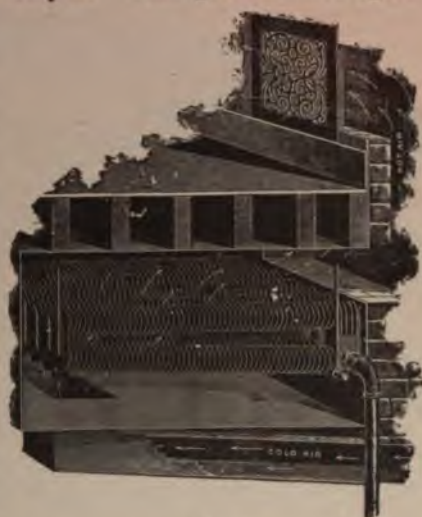


Fig. 7.

through the same. The shape of the sections is such, that when in place, small flues are formed between them. Air is admitted through an opening in the outside wall and in passing upward



Fig. 8.

through these flues becomes heated before entering the room. A switch damper is placed in the duct at the base of the radiator so that the air may be taken from the room itself instead of from out of doors if so desired.

Direct Hot Water. This system is similar in construction to one for direct steam, except that hot water flows through the pipes and radiators instead of steam. It is largely used for the warming of dwelling houses to which it is especially adapted

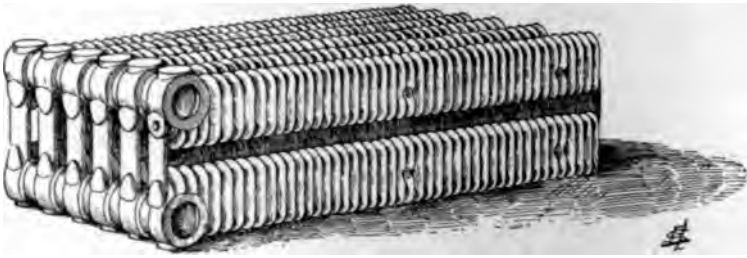


Fig. 9.

owing to the ease with which the temperature of the water can be regulated.

Where steam is used the radiators are always at practically the same temperature, and regulation must be secured by shutting off steam and turning it on at intervals depending on the outside temperature; while with hot water, the radiators can be kept turned on all the time, and regulation secured by varying the temperature of the water flowing through them.

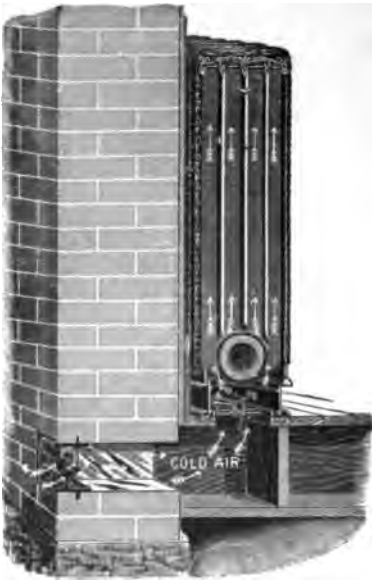


Fig. 11.

There are two distinct systems of circulation employed; one depending on the difference in temperature of the water in the supply and return pipes, called "gravity circulation;" and another where a pump is used to force the water through the mains, called "forced circulation." The former is used for dwellings and other buildings of ordinary size, and the latter for large

buildings, and especially where there are long horizontal runs of pipe.

For gravity circulation some form of sectional cast iron boiler is commonly used although wrought iron tubular boilers may be employed if desired. In the case of forced circulation a heater designed to warm the water by means of live or exhaust steam is often used. A centrifugal or rotary pump of the type shown in



Fig. 10.

Fig. 12 is best adapted to this purpose; this pump may be driven by an electric motor, or a steam engine, as most convenient. Fig. 13 shows the general form of a hot-water radiator, which is similar to those used for steam, except the sections are connected at the top as well as at the bottom; this is shown by the cap over the opening at the top of the end section, which does not appear on the steam radiator shown in Fig. 2. A system for hot-water heating costs more to install than one for steam as the radiators

have to be larger and the piping of larger size and more carefully graded.

Indirect Hot Water. This is used under the same conditions as indirect steam, and the heaters used are similar to those already described. Special attention is given to the form of the



Fig. 13.

sections in order that there may be an even distribution of water through all parts of them. Figs. 14 and 15 show typical hot-water radiators for indirect work. As the stacks are placed in the basement of a building, and only a short distance above the boiler, extra large pipes must be used to secure a proper circulation, for the "head" producing flow is small. The stack casings, cold and warm-air pipes and registers are the same as in steam heating.

Exhaust Steam. Exhaust steam is used for heating in connection with power plants, as in factories and shops or in office buildings which have their own lighting plants. There are two methods of using exhaust steam for heating purposes. One is to carry a back pressure on the engines of from 5 to 10 pounds, depending on the length and size of the pipe mains, and the other is to use some form of "vacuum system" which consists of a pump or ejector attached to the returns from the radiators; this draws the steam through the radiators and tends to reduce the back pressure on the engines rather than to increase it.

Where the first method is used, and a back pressure carried—

either the boiler pressure or the cut-off of the engines must be increased to keep the "mean effective pressure" the same and not reduce the horse-power delivered. In general it is more economical to utilize the exhaust steam for heating. There are instances, however, where the relation between the quantities of steam required for heating and for power are such, especially if the engines are run condensing, that it is better to throw the exhaust away and heat with live steam. Where the vacuum method is used these difficulties are avoided, and for this reason it is coming into more common



Fig. 12.

use. If the condensation from the exhaust steam is returned to the boilers the oil must first be removed; this is usually accomplished by passing the steam through some form of grease extractor as it leaves the engine. The water of condensation is

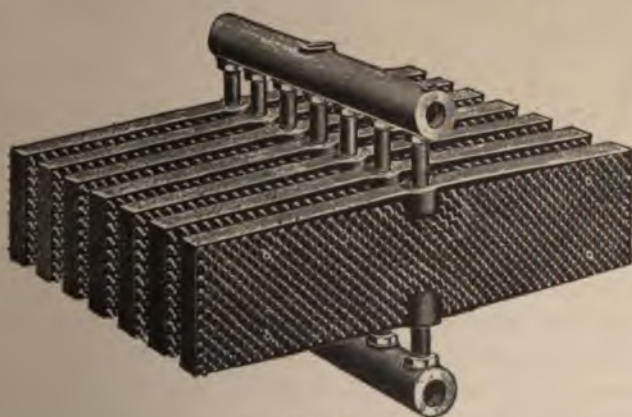


Fig. 14.

Then passed through a separating tank before it is delivered to the return pumps. It is better to remove a portion of the oil before the steam enters the pipes and radiators, else a coating

will be formed on their inner surfaces which will reduce their heating efficiency.

Forced Blast. This method of heating, in different forms, is used for the warming of factories, schools, churches, theatres, halls or any large building where good ventilation is desired. The air for warming is drawn or forced through a heater of special design, and discharged by a fan or blower into ducts which lead to registers placed in the rooms to be warmed. The heater is usually made up in sections so that steam may be admitted to or shut off from any section independently of the others, and the temperature of the air regulated in this manner. Sometimes a by-pass



Fig. 15.

damper is attached, so that part of the air will pass through the heater and part around or over it: in this way the proportions of cold and heated air may be so adjusted as to give the desired temperature to the air entering the rooms. These forms of regulation are common where a blower is used for warming a single room as in the case of a church or hall; but where several rooms are warmed, as in a schoolhouse, it is customary to use the main or primary heater at the blower for warming the air to a given temperature, (somewhat below that which is actually required) and to supplement this by placing secondary coils or heaters at the ends of the flues leading to the different rooms. By this arrangement the temperature of each room can be regulated independently of the others. The so-called double duct system is sometimes employed. In this case two ducts are

ied to each register, one supplying hot air and the other cold or
pered air, and a damper for mixing these in the right propor-

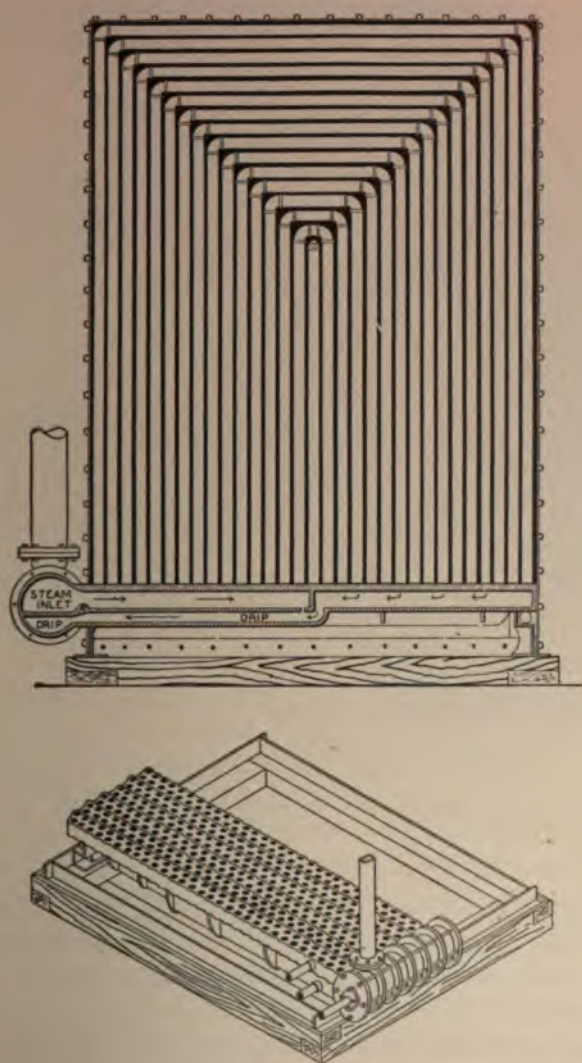


Fig 16.

s is placed in the flue below the register. Fig. 16 shows a
men form of the heater used in connection with a fan ; this is en-

cased in heavy sheet iron or brickwork, and is so connected with the fan that the air is drawn or forced through the spaces between the hot pipes and thus becomes heated. Fig. 17 represents the usual form of fan wheel used for heating and ventilating work; this is enclosed in a steel plate casing with inlet openings at the sides and a discharge outlet at the outer edge of the fan. A common arrangement of fan and heater is shown in Fig. 18. The arrows indicate the cold air entering the heater and the discharge from the fan is through the circular opening at the top of the casing. This fan is shown as being driven by a direct connected engine.



Fig. 17.

Electric motors and steam engines are both used for this purpose and may be either belted or direct connected.

Fig. 19 shows a fan and heater arranged for a double duct system. A portion of the air passes through the heater, the top of which can be seen where the casing is broken away; the remainder of the air passes partly through, and partly over the heater, depending upon the position of the by-pass damper above. The temperature

of the air in the upper duct is therefore less than that in the lower, and the two can be mixed at the registers as required. In Fig. 20 is shown a type of fan called the "cone fan." This is usually placed in an opening in a brick wall and discharges air from its entire perimeter into a room called a "plenum" chamber, with which the various distributing ducts connect.

Electricity. Unless electricity is produced at a very low cost, its use for heating residences or large buildings is not practicable. It has however quite a field of usefulness in the heating of small offices, bath rooms, cold corners of rooms, electric cars, etc., and is often used in rooms which cannot be reached by steam or warm-air pipes.

It has the special advantage of being instantly available, and the amount of heat may be regulated at will.

The heaters are perfectly clean, do not vitiate the air and are portable. They are usually arranged in sections so that the amount of heat can be regulated as desired. They are made up

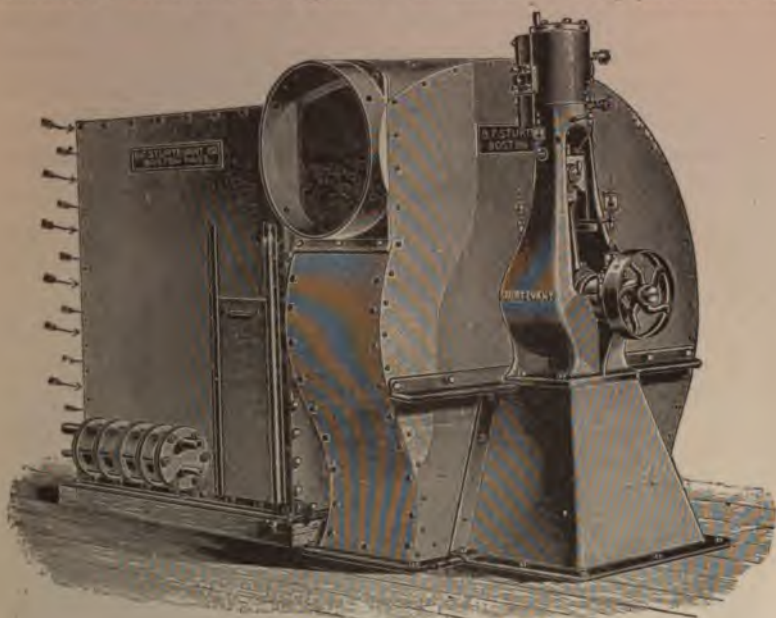


Fig. 18.

of resistance coils embedded in asbestos or some other form of non-conducting material.

Figs. 21, 22 and 23 show different forms of electric radiators; Fig. 22 is designed especially for car heating.

PRINCIPLES OF VENTILATION.

Closely connected with the subject of heating is the problem of maintaining air of a certain standard of purity in the various buildings occupied.

The introduction of pure air can only be done properly in connection with some system of heating, and no system of heating is complete without a supply of pure air, depending in amount upon the kind of building and the purpose for which it is used.

Composition of the Atmosphere. It has already been stated

elsewhere in this work that atmospheric air is not a simple substance but a mechanical mixture. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of one part of oxygen to four parts of nitrogen by weight. Carbonic acid gas, the product of all combustion, exists in the proportion of 3 to 5 parts in 10,000 in the open country. Water in the form of vapor, varies greatly with the temperature, and the exposure of the air to open bodies of water. In addition to the above, there are generally present, in variable but exceedingly small quantities, ammonia, sulphuretted hydrogen, sulphuric, sulphurous, nitric and nitrous acids, floating organic and inorganic matter and local impurities. Air also contains ozone which is a peculiarly active form of oxygen, and lately new constituent gases have been found in small quantities.



Fig. 19.

Oxygen is one of the most important elements of the air, so far as both heating and ventilation are concerned. It is the active element in the chemical process of combustion and also of a somewhat similar process which takes place in the respiration of human beings. Taken into the lungs it acts upon the excess of carbon in the blood, and possibly upon other ingredients, forming chemical compounds which are thrown off in the act of respiration or breathing.

Nitrogen. The principal bulk of the atmosphere is nitrogen, which exists uniformly diffused with oxygen and carbonic acid

gas. This element is practically inert in all processes of combustion or respiration. It is not affected in composition, either by passing through a furnace during combustion or through the lungs in the process of respiration. Its action is to render the oxygen less active and to absorb some part of the heat produced by the process of oxidation.

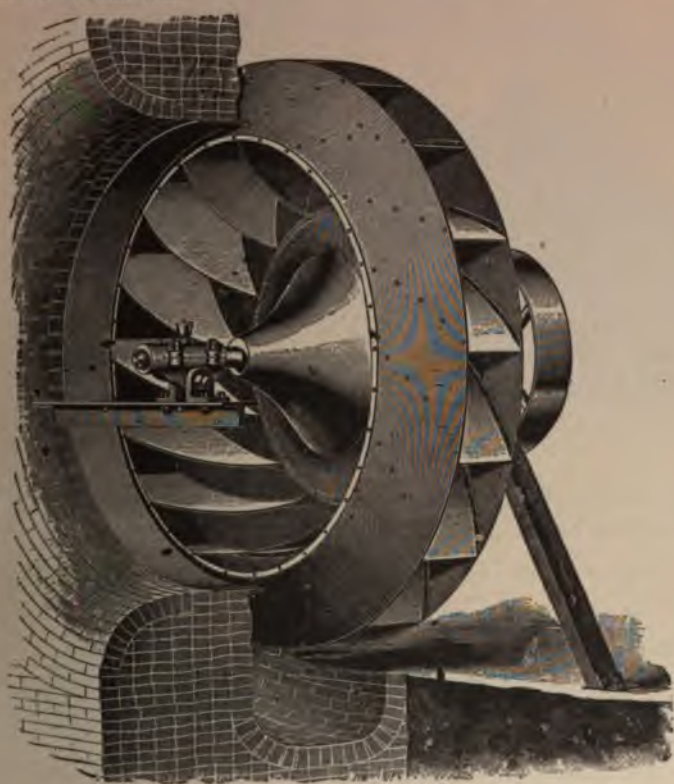


Fig. 20.

Carbonic Acid Gas is of itself only a neutral constituent of the atmosphere, like nitrogen, and contrary to the general impression its presence in moderately large quantities (if uncombined with other substances) is neither disagreeable nor especially harmful. Its presence in the air, however, provided for respiration, decreases the readiness with which the carbon of the blood unites with the oxygen of the air, and therefore, when present in sufficient quantity may cause indirectly, not only serious, but fatal results.

The real harm of a vitiated atmosphere is caused by its other constituent gases and by the minute organisms which are thrown off in the process of respiration. It is known, however, that these other impurities exist in fixed proportion to the amount of carbonic acid present in an atmosphere vitiated by respiration. Therefore, as the relative proportion of carbonic acid may be easily determined by experiment, the fixing of a standard limit of the amount



Fig. 21.

in which it may be allowed, also limits the amounts of other impurities which are found in combination with it.

When carbonic acid is present in excess of 10 parts in 10,000



Fig. 22.

parts of air, a feeling of weariness and stuffiness, generally accompanied by a headache, will be experienced; while with even 8 parts in 10,000 parts a room would be considered close. For general considerations of ventilation the limit should be placed at 6 to 7 parts in 10,000 thus allowing an increase of 2 to 3 parts over that present in outdoor air which may be considered to contain four parts in 10,000 under ordinary conditions.

Analysis of Air. The amount of carbonic acid present in

the air may be readily determined, with sufficient accuracy for practical purposes, in the following manner:

Six clean, dry and tightly corked bottles, containing respectively 100, 200, 250, 300, 350 and 400 cubic centimeters, a glass tube containing exactly 15 cubic centimeters to a given mark, and a bottle of perfectly clear, fresh lime-water make up the apparatus required. The bottles should be filled with the air to be examined by means of a hand-ball syringe. Add to the smallest bottle 15 cubic centimeters of the lime-water, put in the cork and shake well. If the lime-water has a milky appearance the amount of carbonic acid will be at least 16 parts in 10,000. If the contents of the bottle remains clear, treat the bottle of 200 cubic centimeters in the same manner; a milky appearance or turbidity in this would indicate 12 parts in 10,000. In a similar manner, turbidity in the 250 cubic centimeter bottle indicates 10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts and in the 400, less than 6 parts. The ability to conduct more accurate analyses can only be attained by special study and a knowledge of chemical properties and methods of investigation.



Fig. 23.

Air Required for Ventilation. The amount of air required to maintain the standard of purity can be very easily determined provided we know the amount of carbonic acid given off in the process of respiration. It has been found by experiment that the average production of carbonic acid by an adult at rest is about .6 cubic feet per hour. If we assume the proportion of this gas as 4 parts in 10,000 in the external air, and are to allow 6 parts in 10,000 in an occupied room, the gain will be 2 parts in 10,000, or in other words there will be $\frac{2}{10,000} = .0002$ cubic feet of carbonic acid mixed with each cubic foot of fresh air entering the room.

Therefore, if one person gives off .6 cubic feet of carbonic acid per hour it will require $.6 \div .0002 = 3000$ cubic feet of air per person to keep the air in the room at the standard of purity assumed, that is, 6 parts of carbonic acid in 10,000 of air.

VENTILATION.

computed in this manner and
 to be introduced for each person
 of purity:

TABLE I.

CUBIC FEET OF AIR REQUIRED PER PERSON.

PER MINUTE.	PER HOUR.
133	8,000
67	4,000
44	2,667
33	2,000
27	1,600
22	1,333
19	1,151
17	1,000

gives the theoretical quantities of air
 standards of purity, and may be used as a
 in actual practice to use quantities which
 to give good results in different types of
 differ somewhat in their recommendations
 present tendency is toward an increase of

represents good modern practice and may
 give results:

TABLE II.

QUANTITY FOR	CUBIC FEET PER MINUTE.	CUBIC FEET PER HOUR.
	50 to 80	3,000 to 4,800
	50	3,000
	40	2,400
Assembly Halls	25	1,500
	20	1,200

Moving Air. Air is moved for ventilating pur-
 poses, by expansion due to heating; and second

by mechanical means. The effect of heat on the air is to increase its volume and therefore lessen its density or weight, so that it tends to rise and is replaced by the colder air below. The available force for moving air obtained in this way is very small and is quite likely to be overcome by wind or external causes. It will be found in general that the heat used for producing velocity in this manner, when transformed into work in the steam engine, is greatly in excess of that required to produce the same effect by the use of a fan. Ventilation by mechanical means is performed either by pressure or suction. The former is used for delivering fresh air into a building and the latter for removing the foul air from it. By both processes the air is moved without change in temperature, and the force for moving must be sufficient to overcome the effects of wind or changes in outside temperature. Some form of fan is used for this purpose.



Fig. 24.

Measurements of Velocity.

The velocity of air in ventilating ducts and flues is measured directly by an instrument called an anemometer. A common form of this instrument is shown in Fig. 24. It consists of a series of flat vanes attached to an axis, and a series of dials. The revolution of the axis causes motion of the hands in proportion to the velocity of the air, and the result can be read directly from the dials for any given period.

AIR DISTRIBUTION.

The location of the air inlet to a room depends upon the size of the room and the purpose for which it is used. In the case of living rooms in dwelling houses, the registers are placed either in the floor or in the wall near the floor; this brings the warm air in at the coldest part of the room and gives an opportunity for warming or drying the feet if desired. In the case of school rooms where large volumes of warm air at moderate temperatures are required, it is best to discharge it through openings in the wall at

a height of 7 or 8 feet from the floor; this gives a more even distribution as the warmer air tends to rise and hence spreads uniformly under the ceiling; it then gradually displaces other air and the room becomes filled with pure air without sensible currents or drafts. The cooler air sinks to the bottom of the room and can be taken off through ventilating registers placed near the floor. The relative positions of the inlet and outlet are often governed to some extent by the building construction, but if possible they should both be located in the same side of the room. Figs. 25, 26 and 27 show common arrangements.

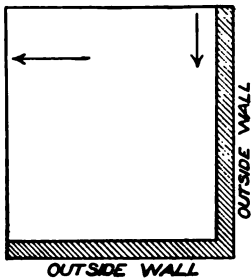


Fig. 25.

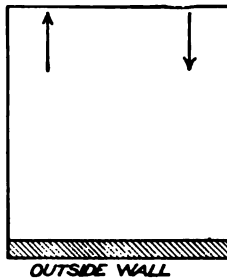


Fig. 26.

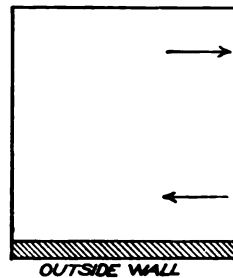


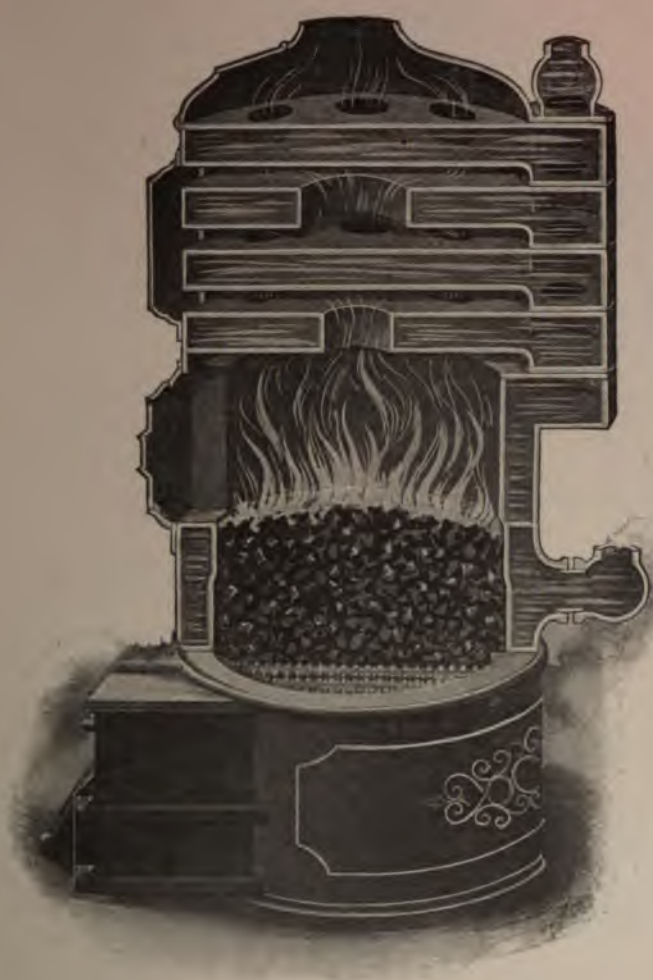
Fig. 27.

The vent outlet should always if possible be placed in an inside wall else it will become chilled and the air-flow through it will become sluggish. In theatres or halls which are closely packed, the air should enter at, or near, the floor in finely-divided streams, and the discharge ventilation should be through openings in the ceiling. The reason for this is the large amount of animal heat given off from the bodies of the audience, which causes the air to become still further heated after entering the room, and the tendency is to rise continuously from floor to ceiling thus carrying away all impurities from respiration as fast as they are given off.

The matter of air velocities, size of flues, etc., will be taken up under the head of design.

HEAT LOSS FROM BUILDINGS.

A British Thermal Unit, or B. T. U., has been defined as the amount of heat required to raise the temperature of one pound of water one degree F. This measure of heat enters into many of



SECTIONAL VIEW OF CAST IRON HOT WATER HEATER.

ASTOR LENOX
TILDEN FOUNDATIONS

the calculations involved in the solving of problems in heating and ventilation, and one should familiarize himself with the exact meaning of the term.

Causes of Heat Loss. The heat loss from a building is due to the following causes; *first*, radiation and conduction of heat through walls and windows; *second*, leakage of warm air around doors and windows and through the walls themselves; and *third*, heat required to warm the air for ventilation.

Loss Through Walls and Windows. The loss of heat through the walls of a building depends upon the material used, the thickness, the number of layers and the difference between the inside and outside temperatures. The exact amount of heat lost in this way is very difficult to determine theoretically, hence we depend principally on the results of experiments.

Loss by Air Leakage. The leakage of air from a room varies from one to two or more changes of the entire contents per hour, depending upon the construction, opening of doors, etc. It is common practice to allow for one change per hour in well-constructed buildings where two walls of the room have an outside exposure. As the amount of leakage depends upon the extent of exposed wall and window surface it seems best to allow for this loss by increasing that due to conduction and radiation. The following table gives the heat losses through different thickness of walls, doors, windows, etc., in B. T. U., per square foot of surface per hour for varying differences in inside and outside temperatures.

Authorities differ considerably in the factors given for heat losses, and there are various methods for computing the same. The following figures and methods have been used extensively in actual practice and have been found to give good results when used with judgment.

TABLE III.

Material.	Difference between inside and outside temperatures.									
	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
8" Brick Wall	5	9	13	18	22	27	31	36	40	45
12" Brick Wall	4	7	10	13	16	20	23	26	30	33
16" Brick Wall	3	5	8	10	13	16	19	22	24	27
20" Brick Wall	2.8	4.5	7	9	11	14	16	18	20	23
24" Brick Wall	2.5	4	6	8	10	12	14	16	18	20
28" Brick Wall	2	3.5	4.5	7	9	11	13	14	16	18
32" Brick Wall	1.5	3	5	6	8	10	11	13	15	16
Single Window	12	24	36	49	60	73	85	93	105	
Double Window	8	16	24	32	40	48	56	62	70	
Single Skylight	11	21	31	42	52	63	73	84	94	
Double Skylight	7	14	20	28	35	42	48	56	62	
1" Wooden Door	4	8	12	16	20	24	28	32	36	40
2" Wooden Door	3	5	8	11	14	17	20	23	25	28
Concrete Floor on Brick Arch	2	4	6.5	9	11	13	15	18	20	22
Wood Floor on Brick Arch	1.5	3	4.5	6	7	9	10	12	13	15
Double Wood Floor	1	2	3	4	5	6	7	8	9	10
Walls of Ordinary Wooden Dwellings	3	5	8	10	13	16	19	22	24	27

For solid stone walls multiply the figures for brick of the same thickness by 1.7. Where rooms have a cold attic above or cellar beneath, multiply the heat loss through walls and windows by 1.1. The figures given in table III. are for a southern exposure; for other exposures multiply the heat loss given in table III. by the factors given in table IV.

TABLE IV.

EXPOSURE.	FACTOR.
N.	1.32
E.	1.12
S.	1.0
W.	1.20
N. E.	1.22
N. W.	1.26
S. E.	1.06
S. W.	1.10
N. E. S. W. or total exposure.	1.16

In order to make the use of the table clear we will give a number of examples illustrating its use.

Assuming an inside temperature of 70°, what will be the heat loss from a room having an exposed wall surface of 200 square

feet and a glass surface of 50 square feet, when the outside temperature is zero. The wall is of brick, 16 inches in thickness and has a southern exposure; the windows are single.

We find from table III. that the factor for a 16" brick wall with a difference in temperature of 70° is 19, and that for glass (single window) under the same condition is 85; therefore

$$\text{Loss through walls} = 200 \times 19 = 3800$$

$$\text{Loss through windows} = 50 \times 85 = 4250$$

$$\text{Total loss per hour} = 8050 \text{ B. T. U.}$$

In computing the heat loss through walls, only those exposed to the outside air are considered.

A room 15 ft. square and 10 ft. high has two exposed walls; one toward the north and the other toward the east. There are 4 windows, each 3' $\times$ 6' in size. The two in the north wall are double while the other two are single. The walls are of brick, 20 inches in thickness; with an inside temperature of 70° what will be the heat loss per hour when it is 10° below zero.

$$\text{Total surface} = 15 \times 10 \times 2 = 300$$

$$\text{Glass surface} = 3 \times 6 \times 4 = 72$$

$$\text{Net wall surface} = 228$$

Difference between inside and outside temperature 80°.

Factor for 20" brick wall is 18.

Factor for single window is 93.

Factor for double window is 62.

The heat losses are as follows:

$$\text{Wall,} \quad 228 \times 18 = 4104$$

$$\text{Single windows,} \quad 36 \times 93 = 3348$$

$$\text{Double windows,} \quad 36 \times 62 = 2232$$

$$9684 \text{ B. T. U.}$$

As one side is toward the north and the other toward the west the actual exposure is N. W. Looking in table IV. we find the correction factor for this exposure to be 1.26; therefore the total heat loss is

$$9684 \times 1.26 = 12,201.84 \text{ B. T. U.}$$

A dwelling house of wooden construction measures 160 ft.

around the outside; it has 2 stories, each 8 ft. in height; the windows are single and the glass surface amounts to $\frac{1}{5}$ the total exposure; the attic and cellar are unwarmed. If 8000 B. T. U. are utilized from each pound of coal burned in the furnace, how many pounds will be required per hour to maintain a temperature of 70° when it is 20° above zero outside.

$$\text{Total exposure} = 160 \times 16 = 2560$$

$$\text{Glass surface} = 2560 \div 5 = 512$$

$$\text{Net wall} = 2048$$

$$\text{Temperature difference} = 70 - 20 = 50^{\circ}$$

$$\text{Wall} \quad 2048 \times 13 = 26624$$

$$\text{Glass} \quad 512 \times 60 = 30720$$

$$\hline 57344 \text{ B. T. U.}$$

As the building is exposed on all sides the factor for exposure will be the average of those for N. E. S. and W. or

$$(1.32 + 1.12 + 1.0 + 1.20) \div 4 = 1.16$$

The house has a cold cellar and attic so we must increase the heat loss 10% for each or 20% for both. Making these corrections we shall have

$$57344 \times 1.16 \times 1.20 = 79822 \text{ B. T. U.}$$

One pound of coal furnishes 8000 B. T. U. then $79822 \div 8000 = 9.97$; or about 10 pounds of coal per hour will be required to warm the building to 70° under the conditions stated.

Approximate Method. For dwelling houses of usual construction the following simple method may be used. Multiply the total exposed surface by 38, which will give the heat loss in B. T. U. per hour for an inside temperature of 70° in zero weather.

This factor is obtained in the following manner. Assume the glass surface to be $\frac{1}{6}$ the total exposure, which is an average proportion.

Then each square foot of exposed surface consists of $\frac{1}{6}$ glass and $\frac{5}{6}$ wall and the heat loss for 70° difference in temperature would be as follows:

$$\text{Wall } \frac{5}{6} \times 19 = 15.8$$

$$\text{Glass } \frac{1}{6} \times 85 = \frac{14.1}{29.9}$$

Increasing this by 16% for total exposure and 10% for loss through ceilings we have $29.9 \times 1.16 \times 1.10 = 38.1$. The loss through floors is considered as being offset by including the kitchen walls of a dwelling house, which are warmed by the range and would not otherwise be included if computing the size of a furnace or boiler for heating.

If the heat loss is required for outside temperatures other than zero, corrections must be made as follows: Multiply by 50 for 20° below zero, by 44 for 10° below, by 33 for 10° above.

This method is convenient for approximations in the case of dwelling houses but the more exact method should be used for other types of buildings, and in all cases for computing the heating surface for separate rooms. When calculating the heat loss from isolated rooms, the cold inside walls as well as the outside must be considered.

The loss through a wall next to a cold attic or other unwarmed space may in general be taken as about two-thirds that of an outside wall.

Heat Loss by Ventilation. One B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees at average temperatures and pressures or will raise 55 cubic feet 1 degree, so that the heat required for the ventilation of any room may be found by the following formula:

$$\frac{\text{cu. ft. of air per hour} \times \text{number of degrees rise}}{55} = \text{B. T. U. required.}$$

To compute the heat loss for any given room which is to be ventilated, first find the loss through walls and windows, and correct for exposure, then compute the amount required for ventilation as above and take the sum of the two. An inside temperature of 70° is always assumed unless otherwise stated.

Example — What quantity of heat will be required to warm 100,000 cubic feet of air to 70° for ventilating purposes when the outside temperature is 10 below zero?

$$100,000 \times 80 \div 55 = 145,454 \text{ B. T. U. Ans.}$$

How many B. T. U. will be required per hour for the ventilation of a church seating 500 people, in zero weather?

Referring to table II. we find that the total air required per hour is $1200 \times 500 = 600,000$ cu. ft.; therefore $600,000 \times 70 \div 55 = 763,636$ B. T. U.

Example.—A corner room in a grammar school $28' \times 32'$ and $12'$ high is to accommodate 50 pupils. The walls are of brick $16''$ in thickness and there are 6 single windows in the room, each $3' \times 6'$; there are warm rooms above and below; the exposure is S. E. How many B. T. U. will be required per hour for warming the room and how many for ventilation, in zero weather?

The total window surface is

$$6 \times 3 \times 6 = 108 \text{ square feet.}$$

The exposed surface of the room is

$$32 \times 12 + 28 \times 12 = 720 \text{ square feet.}$$

The exposed wall surface is

$$720 - 108 = 612 \text{ square feet.}$$

$$\text{Heat loss through windows} = 108 \times 85 = 9180$$

$$\text{Heat loss through walls} = 612 \times 19 = 11628$$

$$\text{Total heat loss} = 20808$$

Total corrected for S. E. exposure

$$= 20808 \times 1.06 = 22,056. \quad \text{Ans.}$$

Air supply required per hour

$$= 2400 \times 50 = 120,000 \text{ cubic feet.}$$

B. T. U. required for ventilation

$$= \frac{120,000 \times 70}{55} = 152,727. \quad \text{Ans.}$$

FURNACE HEATING.

Types of Furnaces. Furnaces may be divided into two general types known as direct and indirect draft. Fig. 28 shows a common form of **direct draft** furnace with a brick setting; the better class have a radiator, generally placed at the top, through which the gases pass before reaching the smoke pipe. They have but one damper usually combined with a cold-air check. Many of the cheaper direct draft furnaces have no radiator at all; the

gases passing directly into the smoke pipe and carrying away much heat that should be utilized.

The furnace shown in Fig. 28 is made of cast iron and has a large radiator at the top ; the smoke connection is shown at the rear.

Fig. 29 represents another form of direct draft furnace. In this case the radiator is made of sheet steel plates riveted together,

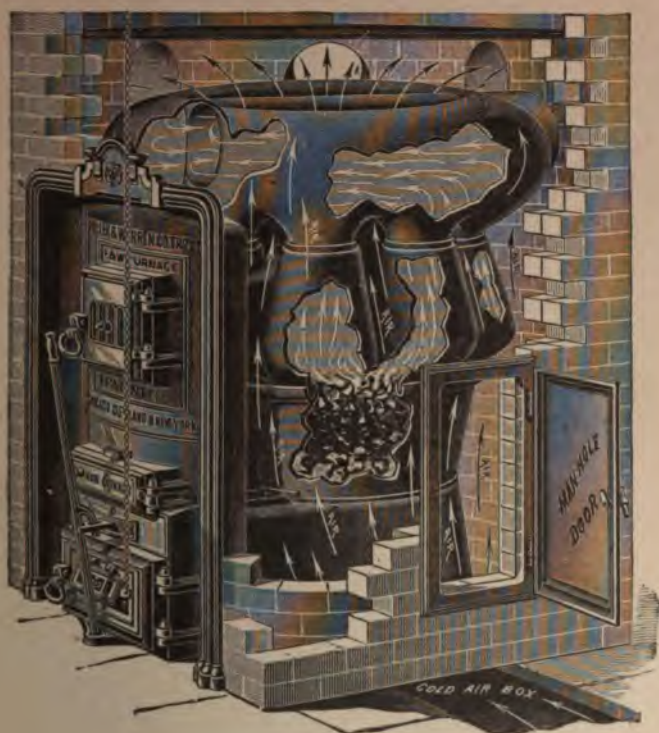


Fig. 28.

and the outer casing is of heavy galvanized iron instead of brick.

In the ordinary **indirect draft** type of furnace (see Fig. 30) the gases pass downward through flues to a radiator located near the base, thence upward, through another flue to the smoke pipe. In addition to the damper in the smoke pipe, a direct draft damper is required to give direct connection with the funnel when coal is first put on, to facilitate the escape of gas to the chimney. When

the chimney draft is weak, trouble from gas is more likely to be experienced with furnaces of this type than with those having a direct draft.

Grates. No part of a furnace is of more importance than the grates. The plain grate rotating about a center pin was for a long time the one most commonly used. These grates were usually

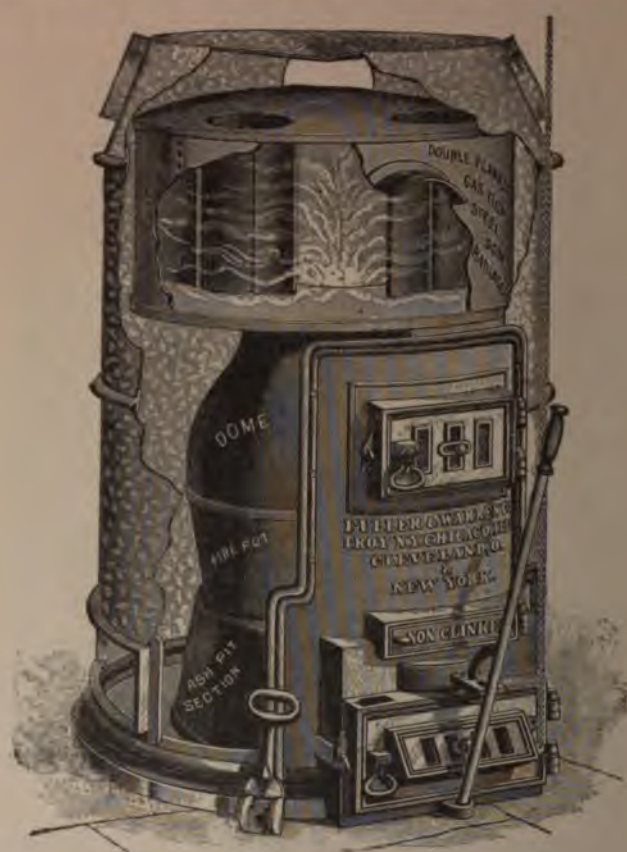


Fig. 29.

provided with a clinker door for removing any refuse too large to pass between the grate bars. The action of such grates tends to leave a cone of ashes in the center of the fire causing it to burn more freely around the edges. A better form of grate is the revolving triangular pattern which is now used in many of the lead-

ing furnaces. It consists of a series of triangular bars having teeth. The bars are connected by gears and are turned by means of a detachable lever. If properly used this grate will cut a slice of ashes and clinkers from under the entire fire with little, if any loss of unconsumed coal.

The Fire Pot. Fire pots are generally made of cast iron or of steel plate lined with fire brick. The depth ranges from about

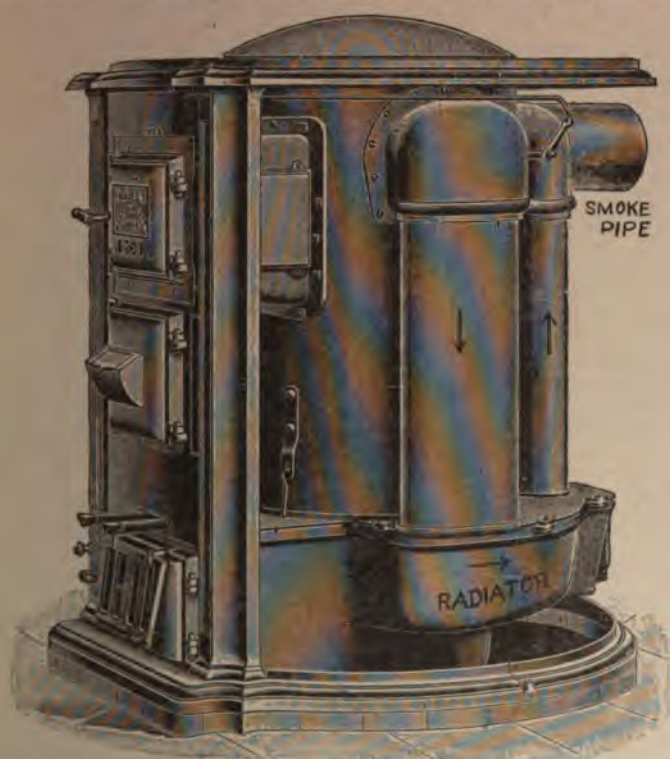


Fig. 30.

12 to 18 inches. In cast iron furnaces of the better class the fire pot is made very heavy to insure durability and to render it less likely to become red hot. The fire pot is sometimes made in two pieces to reduce the liability of cracking. The heating surface is sometimes increased by corrugations, pins or ribs.

A fire brick lining is necessary in a wrought iron or steel furnace to protect the thin shell from the intense heat of the fire.

Since brick lined fire pots are much less effective than cast iron in transmitting heat, such furnaces depend to a great extent for their efficiency on the heating surface in the dome and radiator, and this as a rule is much greater than in those of cast iron.

Cast iron furnaces have the advantage when coal is first put on, (and the drop flues and radiator are cut out by the direct damper) of still giving off heat from the fire pot, while in the case of brick linings very little heat is given off in this way and the rooms are likely to become somewhat cooled before the fresh coal becomes thoroughly ignited.

Combustion Chamber. The body of the furnace above the fire pot, commonly called the dome or feed section, provides a combustion chamber. This chamber should be of sufficient size to permit the gases to become thoroughly mixed with the air passing up through the fire or entering through openings provided for the purpose in the feed door. In a well-designed furnace this space should be somewhat larger than the fire pot.

Radiator. The radiator, so called, with which all furnaces of the better class are provided, acts as a sort of reservoir in which the gases are kept in contact with the air passing over the furnace until they have parted with a considerable portion of their heat. Radiators are built of cast iron, of steel plate or of a combination of the two. The former is more durable and can be made with fewer joints, but owing to the difficulty of casting radiators of large size, steel plate is commonly used for the sides.

The effectiveness of a radiator depends on its form, its heating surface and the difference between the temperature of the gases and the surrounding air. Owing to the accumulation of soot, the bottom surface becomes practically worthless after the furnace has been in use a short time ; surfaces to be effective must therefore be self-cleaning.

If the radiator is placed near the bottom of the furnace the gases are surrounded by air at the lowest temperature, which renders the radiator more effective for a given size than if placed near the top and surrounded by warm air. On the other hand, the cold air has a tendency to condense the gases, and the acids thus formed are likely to corrode the iron.

Heating Surface. The different heating surfaces may be

described as follows: Fire pot surface; surfaces acted upon by direct rays of heat from the fire, such as the dome or combustion chamber; gas or smoke heated surfaces, such as flues or radiators and extended surfaces, such as pins or ribs. Surfaces unlike in character and location, vary greatly in heating power, so that in making comparisons of different furnaces we must know the kind, form and location of the heating surfaces as well as the area.

In some furnaces having an unusually large amount of surface, it will be found on inspection that a large part would soon become practically useless from the accumulation of soot. In others a large portion of the surface is lined with fire brick, or is so situated that the air currents are not likely to strike it.

The ratio of grate to heating surface varies somewhat according to the size of furnace. It may be taken as varying from 1 to 25 in the smaller sizes and 1 to 15 in the larger.

Efficiency. One of the first items to be determined in estimating the heating capacity of a furnace is its efficiency, that is, the proportion of the heat in the coal that may be utilized for warming. The efficiency depends chiefly on the area of the heating surface as compared with the grate, on its character and arrangement, and on the rate of combustion. The usual proportions between grate and heating surface have been stated. The rate of combustion required to maintain a temperature of 70° in the house depends of course on the outside temperature. In very cold weather a rate of 4 to 5 pounds of coal per square foot of grate per hour must be maintained.

One pound of good anthracite coal will give off about 13000 B. T. U. and a good furnace should utilize 70 per cent. of this heat. The efficiency of an ordinary furnace is often much less, sometimes as low as 50 per cent.

In estimating the required size of a first-class furnace with good chimney draft we may safely count upon a maximum combustion of 5 pounds of coal per square foot of grate per hour, and may assume that 8000 B. T. U. will be utilized for warming purposes from each pound burned. This quantity corresponds to an efficiency of 60 per cent.

Heating Capacity. Having determined the heat loss from a building by the methods given, it is a simple matter to compute

the size of grate necessary to burn a sufficient quantity of coal to furnish the amount of heat required for warming.

As a matter of illustration we may consider the heat delivered to the rooms as made up of two parts; first, that required to warm the outside air up to 70° (the temperature of the rooms) and second, the quantity which must be added to this to offset the loss through walls and windows. Air is usually delivered at the registers at about 140 degrees under zero conditions outside; this air leaves the rooms by leakage at a temperature of 70 degrees, (the normal inside temperature) having lost one-half its heat by conduction, radiation, etc., so that the heat given to the entering air must be twice that which we have computed for loss through walls, etc.

Example. — The loss through the walls and windows of a building is found to be 80000 B. T. U. per hour in zero weather, what will be the size of furnace required to maintain an inside temperature of 70 degrees?

From the above we have the total heat required, equal to $80000 \times 2 = 160000$ B. T. U. per hour. If we assume that 8000 B. T. U. are utilized per pound of coal, then $160000 \div 8000 = 20$ pounds of coal required per hour, and if 5 pounds can be burned on each square foot of grate per hour, then $\frac{20}{5} = 4$ square feet required. A fire pot 28 inches in diameter has an area of 4.27 square feet and is the size we should use.

The following table will be found useful in determining the diameter of fire pot required:

TABLE V.

AVERAGE DIAMETER OF FIRE POT IN INCHES.	AREA IN SQUARE FEET.
18	1.77
20	2.18
22	2.64
24	3.14
26	3.69
28	4.27
30	4.91
32	5.58

If the outside temperature is below zero the method of computation becomes slightly different. We have seen that in zero weather a certain quantity of heat is required to raise the temperature of the entering air from zero to 70° , the temperature of the room, and that a second quantity must then be added to raise the temperature of the air to 140° , which is the usual temperature of delivery at the registers. This last quantity is to offset that lost by radiation and conduction, and must equal the heat loss from the building as computed by the factors given in tables III. and IV. The air has been raised through 140 degrees and $\frac{70}{140}$ of the heat supplied has been used to raise it to the temperature of the room and has been lost by leakage; while the remaining $\frac{70}{140}$, an equal amount, has been given up by radiation and conduction. In this case we have only to compute the heat loss for radiation and conduction by the rules given and multiply this result by 2 to obtain the total amount of heat to be supplied by the furnace.

Now take a case where it is 10 degrees below zero. If the air is delivered to the rooms at 140 degrees as before, it must be warmed through 150 degrees. Of the heat supplied $\frac{80}{150}$ has been used to raise the temperature of the outside air to that of the room, and only $\frac{70}{150}$ for loss by radiation and conduction. As in the preceding example, this latter quantity must equal the computed heat loss through walls and windows; and as it is only $\frac{70}{150}$ or .466 of the total amount of heat required we must multiply it by $1 \div .466 = 2.14$ instead of by 2 as in the first case where the outside temperature is zero.

In the same manner multiply by 2.28 for 20 degrees below zero and by 2.42 for 30 degrees.

Example.—A brick house is 20 feet wide, and has 4 stories, each being 10 feet in height. The house is one of a block and is exposed only at the front and rear. The walls are 16 inches thick and the block is so sheltered that no correction need be made for exposure. Single windows make up $\frac{1}{3}$ the total exposed surface. Figure for cold attic but warm basement. What area of grate surface will be required for a furnace to keep

the house at 70° when it is 10° below zero outside?

Exposed surface = $2 \times 20 \times 40 = 1600$ sq. ft.

Loss through windows = $200 \times 93 = 18,600$ B. T. U.

Loss through walls = $1400 \times 22 = 30,800$

Loss through walls and windows = 49,400

Entire heat loss, allowing for attic

= $49,400 \times 1.1 = 54,340$ B. T. U.

B. T. U. required = $54,340 \times 2.14 = 116,288$

$\frac{116,288}{5 \times 8000} = 2.90$ sq. ft. of grate. Ans.

Location of Furnace. A furnace should be so placed that the warm-air pipes will be of nearly the same length. The air travels most readily through pipes leading toward the sheltered side of the house and to the upper rooms. Therefore pipes leading toward the north or west or to rooms on the first floor should be favored in regard to length and size. The furnace should be placed somewhat to the north or west of the center of the house or toward the points of compass from which the prevailing winds blow.

Smoke Pipes. Furnace smoke pipes range in size from about 6 inches in the smaller sizes to 8 or 9 inches in the larger ones. They are generally made of galvanized iron of No. 24 gauge or heavier. The pipe should be carried to the chimney as directly as possible, avoiding bends which increase the resistance and diminish the draft. Where a smoke pipe passes through a partition it should be protected by a soapstone or double perforated metal collar having a diameter at least 8 inches greater than that of the pipe. The top of the smoke pipe should not be placed within 8 inches of unprotected beams nor less than 6 inches under beams protected by asbestos or plaster with a metal shield beneath. A collar to make tight connection with the chimney should be riveted to the pipe about 5 inches from the end to prevent its being pushed too far into the flue. Where the pipe is of unusual length it is well to cover it to prevent loss of heat and the condensation of smoke.

Chimney Flues. Chimney flues if built of brick should have walls 8 inches in thickness, unless terra cotta linings are used, when only 4 inches of brick work is required. Except in small houses where an 8 × 8 flue may be used, the nominal size of the

smoke flue should be at least 8×12 to allow for contractions or offsets. A clean-out door should be placed at the bottom of the flue for removing ashes and soot. A square flue cannot be reckoned at its full area as the corners are of little value. To avoid down drafts the top of the chimney must be carried above the highest point of the roof unless provided with a suitable hood or top.

Cold-Air Box. The cold-air box should be large enough to supply a volume of air sufficient to fill all the hot-air pipes at the same time. If the supply is too small, the distribution is sure to be unequal and the cellar will become overheated from lack of air to carry away the heat generated.

If a box is made too small or is throttled down so that the volume of air entering the furnace is not large enough to fill all the pipes it will be found that those leading to the less exposed side of the house or to the upper rooms will take the entire supply, and that additional air to supply the deficiency will be drawn down through registers in rooms less favorably situated. It is common practice to make the area of the cold-air box three-fourths the combined area of the hot-air pipes. The inlet should be placed where the prevailing cold winds will blow into it; this is commonly on the north or west side of the house. If it is placed on the side away from the wind, warm air from the furnace is likely to be drawn out through the cold-air box.

Whatever may be the location of the entrance to the cold-air box, changes in the direction of the wind may take place which will bring the inlet on the wrong side of the house. To prevent the possibility of such changes affecting the action of the furnace the cold-air box is sometimes extended through the house and left open at both ends, with check-dampers arranged to prevent back drafts. These checks should be placed some distance from the entrance to prevent their becoming clogged with snow or sleet. The cold-air box is generally made of matched boards, but galvanized iron is much better; it costs more than wood but is well worth the extra expense on account of tightness which keeps the dust and ashes from being drawn into the furnace casing to be discharged through the registers into the rooms above.

The cold-air inlet should be covered with galvanized wire

netting with a mesh of at least three-eighths of an inch. The frame to which it is attached should not be smaller than the inside dimensions of the cold-air box. A door to admit air from the cellar to the cold-air box is generally provided. As a rule air should be taken from this source only when the house is temporarily unoccupied or during high winds.

Return Duct. In some cases it is desirable to return air to the furnace from the rooms above, to be reheated. Ducts for this purpose are common in places where the winter temperature is

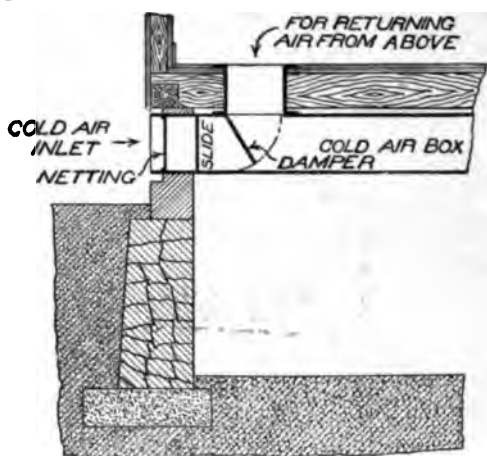


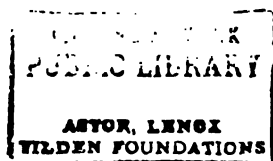
Fig. 31.

frequently below zero. Return ducts when used, should be in addition to the regular cold-air box. Fig. 31 shows a common method of making the connection between the two. By proper adjustment of the swinging damper the air can be taken either from out of doors or through the register from the room above. The return

register is often placed in the hallway of a house so that it will take the cold air which rushes in when the door is opened and also that which may leak in around it while closed. Check valves or flaps of light gossamer or woolen cloth should be placed between the cold-air box and the registers to prevent back drafts during winds.

The return duct should not be used too freely at the expense of outdoor air, and its use is not recommended except during the night when air is admitted to the sleeping rooms through open windows.

Warm-Air Pipes. The required size of the warm-air pipe to any given room depends upon the heat loss from the room and the volume of warm air required to offset this loss. Each cubic foot of air warmed from zero to 140 degrees brings into a room 2.2 B. T. U. We have already seen that in zero weather with the air





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entering the registers at 140 degrees, only one-half of the heat contained in the air is available for offsetting the losses by radiation and conduction, so that only 1.1 B. T. U. in each cubic foot of entering air, can be utilized for warming purposes. Therefore if we divide the computed heat loss in B. T. U. from a room, by 1.1 it will give the number of cubic feet of air at 140 degrees necessary to warm the room in zero weather.

As the outside temperature becomes colder the quantity of heat brought in per cubic foot of air increases, but the proportion available for warming purposes becomes less at nearly the same rate, so that for all practical purposes we may use the figure 1.1 for all usual conditions. In calculating the size of pipe required, we may assume maximum velocities of 280 and 400 feet per minute for rooms on the first and second floors respectively. Knowing the number of cubic feet of air per minute to be delivered, we can divide it by the velocity, which will give us the required area of the pipe in square feet.

Round pipes of tin or galvanized iron are used for this purpose. The following table will be found useful in determining the required diameters of pipe in inches.

TABLE VI.

DIA. OF PIPE IN INCHES.	AREA IN SQ. INCHES.	AREA IN SQUARE FEET.
6	28	.196
7	38	.267
8	50	.349
9	64	.442
10	79	.545
11	95	.660
12	113	.785
13	133	.922
14	154	1.07
15	177	1.23
16	201	1.40

Example. — The heat loss from a room on the second floor is 22,000 B. T. U., per hour. What diameter of warm air pipe will be required?

$22,000 \div 1.1 = 20,000 =$ cubic feet of air required per hour.
 $20,000 \div 60 = 333$ per minute. Assuming a velocity of 400 feet per minute we have $333 \div 400 = .832$ square feet, which is the area of pipe required. Referring to table VI. we find this comes between a 12 and 13-inch pipe and the larger size would probably be chosen.

Example.— A first floor room has a computed loss of 33,000 B. T. U. per hour when it is 10° below zero. The air for warming is to enter through two pipes of equal size, and at a temperature of 140 degrees. What will be the required diameter of the pipes?

There will be needed $33,000 \div 1.1 = 30,000$ cubic feet of air per hour, or 500 cubic feet per minute. At a velocity of 280 feet per minute, the pipe area must be $500 \div 280 = 1.786$. This is conveniently obtained by two 13-inch pipes.

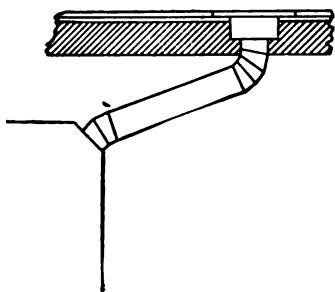


Fig. 32

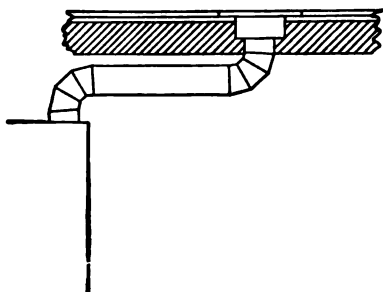


Fig. 33.

Since long horizontal runs of pipe increase the resistance and loss of heat, they should not in general be over 15 feet in length. This applies especially to pipes leading to rooms on the first floor or to those on the cold side of the house. Pipes of excessive length should be increased in size because of the added resistance.

Figs. 32 and 33 show common methods of running the pipes in the basement. The first gives the best results and should be used where the basement is of sufficient height to allow it. A damper should be placed in each pipe near the furnace for regulating the flow of air to the different rooms or for shutting them off entirely when desired.

While round pipe risers give the best results, it is not always possible to provide a sufficient space for them, and flat or oval pipes are substituted. When vertical pipes must be placed in single partitions, much better results will be obtained if the studding can be made 5 or 6 inches deep instead of 4 as is usually done. Flues should never in any case be made less than $3\frac{1}{2}$ inches in depth. Each room should be heated by a separate pipe. In some cases however, it is allowable to run a single riser to heat two unimportant rooms on an upper floor. A clear space of at least $\frac{1}{2}$ inch should be left between the risers and studs and the latter should be carefully tinned, and the space between them on both sides covered with tin, asbestos or wire lath.

The following table gives the capacity of oval pipes. A 6-inch pipe ovaled to 5 means that a 6-inch pipe has been flattened out to a thickness of 5 inches and column 2 gives the resulting area.

TABLE VII.

DIMENSION OF PIPE.	AREA IN SQUARE INCHES.
6 ovaled to 5	27
7 " " $\frac{1}{2}$	31
7 " " $3\frac{1}{2}$	29
7 " " 6	38
8 " " 5	43
9 " " 4	45
10 " " $3\frac{1}{2}$	46
9 " " 6	57
9 " " 5	51
11 " " 4	58
12 " " $3\frac{1}{2}$	55
10 " " 6	67
11 " " 5	67
14 " " 4	76
15 " " $3\frac{1}{2}$	73
12 " " 6	85
12 " " 5	75
19 " " 4	96
20 " " $3\frac{1}{2}$	100

Having determined the size of round pipe required, an equiva-

lent oval pipe can be selected from the table to suit the space available.

Registers. The registers which control the supply of warm air to the rooms, generally have a net area equal to two-thirds of their gross area. The net area should be from 10 to 20 per cent greater than the area of the pipe connected with it. It is common practice to use registers having the short dimension equal to, and the long dimension about one-half greater than the diameter of the pipe. This would give the following standard sizes for different diameters of pipe.

TABLE VIII.

DIAMETER OF PIPE.	SIZE OF REGISTER.
6	6 × 10
7	7 × 10
8	8 × 12
9	9 × 14
10	10 × 15
11	11 × 16
12	12 × 17
13	14 × 20
14	14 × 22
15	15 × 22
16	16 × 24

Combination Systems. A combination system for heating by hot air and hot water consists of an ordinary furnace with some form of surface for heating water, placed either in contact with the fire or suspended above it. Fig. 34 shows a common arrangement where part of the heating surface forms a portion of the lining to the fire pot and the remainder is above the fire.

Care must be taken to properly proportion the work to be done by the air and the water, else one will operate at the expense of the other. One square foot of heating surface in contact with the fire is capable of supplying from 40 to 50 square feet of radiating surface, and one square foot suspended over the fire will supply from 15 to 25 square feet of radiation.

Care and Management. The following general rules apply to the management of all hard coal furnaces.

The fire should be thoroughly shaken once or twice daily in cold weather. It is well to keep the fire pot heaping full at all times. In this way a more even temperature may be maintained, less attention required and no more coal burned than when the

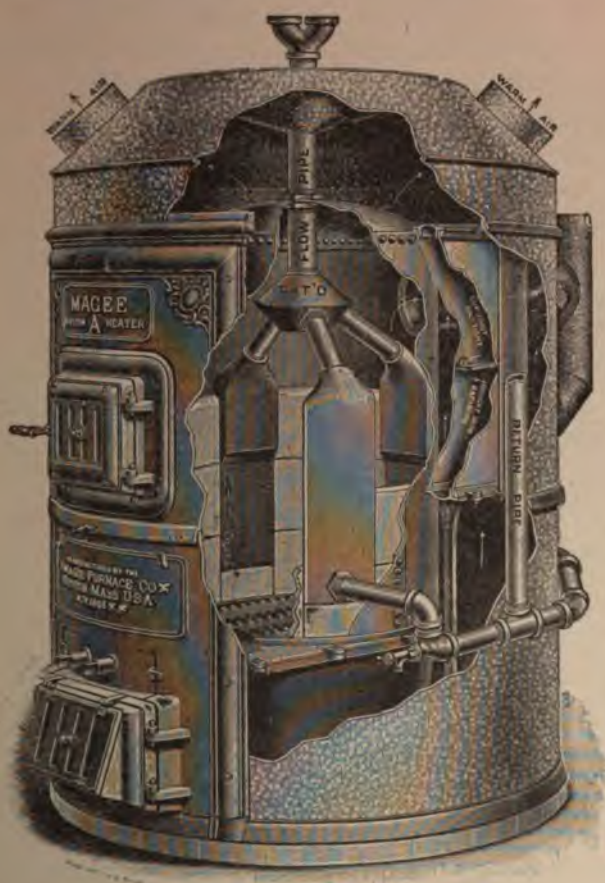


Fig. 34.

pot is only partly filled. In mild weather the mistake is frequently made of carrying a thin fire, which requires frequent attention and is likely to die out. Instead, to diminish the temperature in the house, keep the fire pot full and allow ashes to accumulate on the grate (not under it) by shaking less frequently

or less vigorously. The ashes will hold the heat and render it an easy matter to maintain and control the fire. When feeding coal on a low fire, open the drafts and neither rake nor shake the fire till the fresh coal becomes ignited. The air supply to the fire is of the greatest importance. An insufficient amount results in incomplete combustion and a great loss of heat. To secure proper combustion the fire should be controlled principally by means of the ash pit, through the ash pit door or slide.

The smoke pipe damper should be opened only enough to carry off the gas or smoke and to give the necessary draft. The openings in the feed door act as a check on the fire and should be kept closed during cold weather, except just after firing, when with a good draft they may be partly opened to increase the air supply and promote the proper combustion of the gases.

Keep the ash pit clear to avoid warping or melting the grate. The cold-air box should be kept wide open except during winds or when the fire is low. At such times it may be partly, but never completely closed. Too much stress cannot be laid on the importance of a sufficient air supply to the furnace. It costs little if any more to maintain a comfortable temperature in the house night and day than to allow the rooms to become so cold during the night that the fire must be forced in the morning to warm them up to a comfortable temperature.

In case the warm air fails at times to reach certain rooms it may be forced into them by temporarily closing the registers in other rooms. The current once established will generally continue after the other registers have been opened.

It is best to burn as hard coal as the draft will warrant. Egg size is better than larger coal, since for a given weight small lumps expose more surface and ignite more quickly than larger ones. The furnace and smoke pipe should be thoroughly cleaned once a year. This should be done just after the fire has been allowed to go out in the spring.

STEAM BOILERS.

Types. The boilers used for heating are the same as have already been described for power work. In addition there is the

cast-iron sectional boiler, which is almost exclusively used for dwelling houses.

Sectional Boilers. Fig. 35 shows a common form of cast-iron boiler. It is made up of slabs or sections, each one of which is connected by nipples with headers at the sides and top. The top header acts as a steam drum and the lower ones act as mud drums; they also receive the water of condensation from the radiators. The gases from the fire pass backward and forward

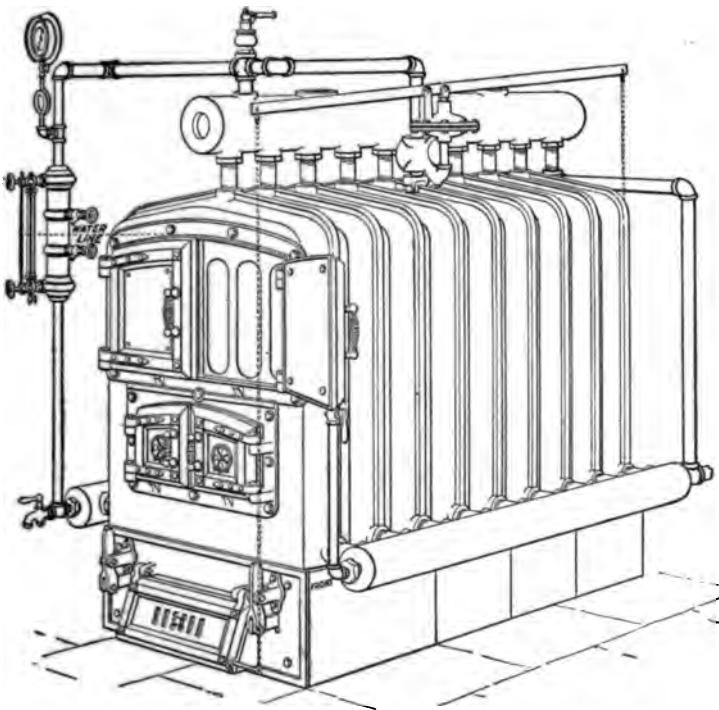


Fig. 35.

through flues and are finally taken off at the rear of the boiler. The ratio of heating to grate surface in this type of boiler ranges from 15 to 25 in the best makes. They are provided with the usual attachments, such as pressure gage, water glass, gage cocks and safety valve; a low-pressure damper regulator is furnished for operating the draft doors, thus keeping the steam pressure practically constant. A pressure of from 1 to 5 pounds is usually

carried on these boilers depending upon the outside temperature. The usual setting is simply a covering of some kind of non-conducting material like plastic magnesia or asbestos, although some forms are enclosed in light brickwork. Fig. 36 shows one of this kind with part of the setting removed. In computing the required size we may proceed in the same manner as in the case

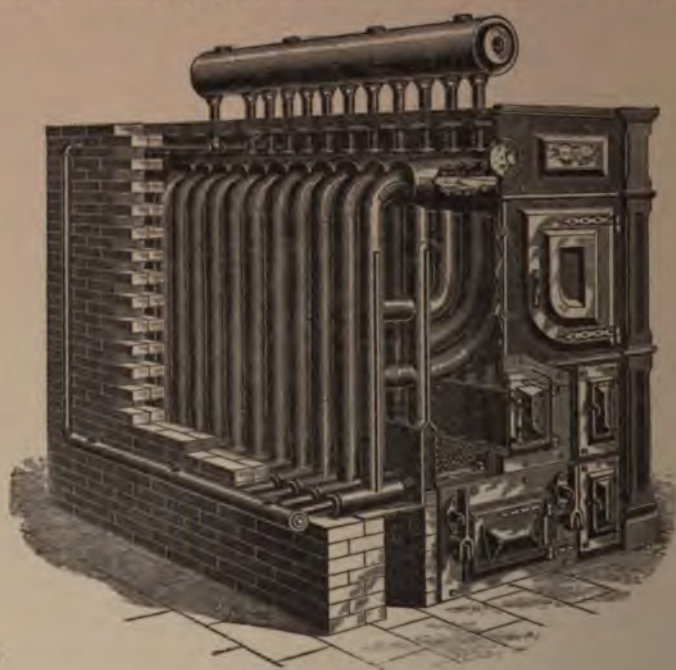


Fig. 36.

of a furnace. For the best types we may assume a combustion of 5 pounds of coal per square foot of grate per hour, and an average efficiency of 60 per cent, which corresponds to 8,000 B. T. U. per pound of coal, available for useful work.

In the case of direct steam heating we have only to supply heat to offset that lost by radiation and conduction, so the grate area may be found by dividing the computed heat loss per hour by 8,000 which gives the number of pounds of coal, and this in turn divided by 5 will give the area of grate required. The most efficient rate of combustion will depend somewhat upon the ratio between the grate and heating surface. It has been found by

experiment that about $\frac{1}{4}$ of a pound of coal per hour for each square foot of heating surface gives the best results, so that by knowing the ratio of heating surface to grate area for any make of heater we may easily compute the most efficient rate of combustion and from it determine the necessary grate area.

For example—The heat loss from a building is 480,000 B. T. U. per hour; we wish to use a heater in which the ratio of heating surface to grate area is 24, what will be the most efficient rate of combustion and the required grate area? $480,000 \div 8,000 = 60$ pounds of coal per hour, and $24 \div 4 = 6$, which is the best rate of combustion to employ, therefore $60 \div 6 = 10$, the grate area required.

Example.—The heat loss from a building is 168,000 B. T. U. per hour and the chimney draft is such that not over 3 pounds of coal per hour can be burned per square foot of grate. What ratio of heating to grate area will be necessary and what will be the required grate area?

The coal necessary is $168,000 \div 8000 = 21$ pounds per hour, requiring 7 square feet of grate surface at the given rate of combustion. Allowing $\frac{1}{4}$ pound per square foot, we need $21 \div \frac{1}{4} = 84$ square feet of heating surface, and this gives a ratio of $84 \div 7 = 12$. Ans.

Cast iron sectional boilers are used for dwelling houses, small schoolhouses, churches, etc., where low pressures are carried. They are increased in size by adding more slabs or sections. After a certain length is reached the rear sections become less and less efficient, thus limiting the size and power.

Tubular Boilers. Tubular boilers are largely used for heating purposes, and are adapted to all classes of buildings except dwelling houses and the special cases mentioned for which sectional boilers are preferable. The capacity of this type of boiler is usually stated as so many horse-power, and the method of determining the size is different from that just described. A boiler horse-power has been defined as the evaporation of $34\frac{1}{2}$ pounds of water from and at a temperature of 212 degrees, and in doing this 83,317 B. T. U. are absorbed, which are again given out when the steam is condensed in the radiators. Hence to find the boiler H. P. required for warming any given building we have only to

compute the heat loss per hour by the methods already given and divide the result by 33,330. It is more common to divide by the number 33,000, which gives a slightly larger boiler and is on the side of safety. The ratio of heating to grate surface in this type of boiler ranges from 30 to 40 and therefore allows a combustion of from 8 to 10 pounds of coal per square foot of grate. This is easily obtained with a good chimney draft and careful firing. The larger the boiler, the more important the plant usually, and the greater the care bestowed upon it so that we may generally count on a higher rate of combustion and a greater efficiency as the size of the boiler increases. The following table will be found useful in determining the size of boiler required under different conditions. The grate area is computed for an evaporation of 8 pounds of water per pound of coal, which corresponds to an efficiency of about 60 per cent and is about the average obtained in practice for heating boilers.

The areas of uptake and smoke pipe are figured on a basis of 1 square foot to 7 square feet of grate surface and the results given in round numbers. In the smaller sizes the relative size of smoke pipe is greater. The rate of combustion runs from 6 pounds in the smaller sizes to $11\frac{1}{2}$ in the larger. Boilers of the proportions given in the table, correspond well with those used in actual practice and may be relied upon to give good results under all ordinary conditions.

Water-tube boilers are often used for heating purposes but more especially in connection with power plants. The method of computing the required H. P. is the same as for tubular boilers.

Horse Power for Ventilation. We already know that one B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees, or it will raise 100 cubic feet $\frac{1}{55}$ of 55 or $\frac{55}{100}$ of 1 degree, therefore to raise 100 cubic feet 1 degree it will take $1 \div \frac{55}{100}$ or $\frac{100}{55}$ B. T. U., and to raise 100 cubic feet through 100 degrees it would take $\frac{100}{55} \times 100$ B. T. U. In other words, the B. T. U. required to raise any given volume of air through any number of degrees in temperature is equal to

$$\frac{\text{Volume of air in cubic ft.} \times \text{Degrees raised}}{55}$$

TABLE IX.

Diameter of shell in inches.	Number of Tubes.	Diameter of Tubes in inches.	Length of Tubes in Feet.	Horse Power.	Size of Grate in inches.	Size of Uptake in inches.	Size of smokepipe in sq. in.
30	28	2½	6	8.5	24 x 36	10 x 14	140
			7	9.9	24 x 36	10 x 14	140
			8	11.2	24 x 36	10 x 14	140
			9	12.6	24 x 42	10 x 14	140
			10	14.0	24 x 42	10 x 14	140
36	34	2½	8	13.6	30 x 36	10 x 16	160
			9	15.3	30 x 42	10 x 18	180
			10	16.9	30 x 42	10 x 18	180
			11	18.6	30 x 48	10 x 20	200
			12	20.9	30 x 48	10 x 20	200
42	34	3	9	18.5	36 x 42	10 x 20	200
			10	20.5	36 x 42	10 x 20	200
			11	22.5	36 x 48	10 x 25	250
			12	24.5	36 x 48	10 x 25	250
			13	26.5	36 x 48	10 x 28	280
48	44	3	14	28.5	36 x 54	10 x 28	280
			10	30.4	42 x 48	10 x 28	280
			11	33.2	42 x 48	10 x 28	280
			12	35.7	42 x 54	10 x 32	320
			13	38.3	42 x 54	10 x 32	320
54	54	3	14	40.8	42 x 60	10 x 36	360
			15	43.4	42 x 60	10 x 36	360
			16	45.9	42 x 60	10 x 36	360
			11	34.0	48 x 54	10 x 38	380
			12	37.7	48 x 54	10 x 38	380
60	46	3½	13	40.8	48 x 54	10 x 38	380
			14	43.6	48 x 54	10 x 38	380
			15	47.0	48 x 60	10 x 40	400
			16	50.1	48 x 60	10 x 40	400
			17	53.0	48 x 60	10 x 40	400
66	72	3	12	48.4	54 x 60	12 x 40	460
			13	52.4	54 x 60	12 x 40	460
			14	56.4	54 x 60	12 x 40	460
			15	60.4	54 x 66	12 x 42	500
			16	64.4	54 x 66	12 x 42	500
72	64	3½	17	71.4	54 x 72	12 x 48	550
			18	75.6	54 x 72	12 x 48	550
	90	3	14	70.1	60 x 66	12 x 48	500
			15	75.0	60 x 72	12 x 52	620
			16	80.0	60 x 72	12 x 52	620
78	78	3½	17	86.0	60 x 78	12 x 56	670
			18	91.1	60 x 78	12 x 56	670
			19	96.2	60 x 78	12 x 56	670
			20	93.1	60 x 78	12 x 56	670
			14	87.4	66 x 72	12 x 56	670
84	114	3	15	93.6	66 x 72	12 x 56	670
			16	99.7	66 x 78	12 x 62	740
			17	106.4	66 x 78	12 x 62	740
			18	112.6	66 x 84	12 x 66	790
			19	118.8	66 x 84	12 x 66	790
90	128	3½	20	127.3	66 x 84	12 x 66	790
			20	107.3	66 x 84	12 x 66	790

Example — How many B. T. U. are required to raise 100,000 cubic feet of air 70 degrees?

$$\frac{100,000 \times 70}{55} = 127,272 +$$

To compute the H. P. required for the ventilation of a building we multiply the total air supply in cubic feet per hour by the number of degrees through which it is to be raised, and divide the result by 55. This gives the B. T. U. per hour, which divided by 33,000 will give the H. P. required. In using this rule always take the air supply in cubic feet per hour.

Example.— A high school has 10 class rooms, each occupied by 50 pupils. Air is to be delivered to the rooms at a temperature of 70 degrees. What will be the total H. P. required to heat and ventilate the building when it is 10 degrees below zero if the heat loss through walls and windows is 1,320,000 B. T. U. per hour?

Cubic feet of air = $3000 \times 10 \times 50 = 1,500,000$

To heat this quantity we need

$$\frac{1,500,000 \times 80}{5.5} = 2,181,800 \text{ B. T. U.}$$

Total B. T. U. = $1,500,000 + 2,181,800 = 3,501,800$

Boiler H. P. = $3,501,800 \div 33,000 = 106$. Ans.

DIRECT STEAM HEATING.

Types of Radiating Surface. The radiation used in direct steam heating is made up of cast iron radiators of various forms, pipe radiators and circulation coils.

Cast Iron Radiators. The general form of cast iron sectional radiators has been shown in Fig. 2. They are made up of sections, the number depending upon the amount of heating surface required. Fig. 37 shows an intermediate section of a radiator of this type. It is simply a loop with inlet and outlet at the bottom. The end sections are the same, except they have legs as shown in Fig. 38. These sections are connected at the bottom by special nipples so that steam entering at the end fills the bottom of the radiator, and being lighter than the air rises through the loops and forces the air downward and toward the farther end, where it is discharged through an air-valve placed about midway

of the last section. There are many different designs varying in height and width, to suit all conditions. The wall pattern shown in Fig. 4 is very convenient when it is desired to place the radiator above the floor, as in bath rooms, etc. ; it is also a convenient form to place under the windows of halls and churches to counteract the effect of cold down drafts. It is adapted to nearly every place where the ordinary direct radiator can be used and may be connected up in different ways to meet the various requirements.

Pipe Radiators. This type of radiator (see Fig. 3) is made up of wrought iron pipes screwed into a cast iron base. The pipes are either connected in pairs at the top by return bends or each separate tube has a thin metal diaphragm passing up the center nearly to the top. It is necessary that a loop be formed else a "dead end" would occur. This would become filled with air and prevent steam from entering, thus causing portions of the radiator to remain cold. For a given surface the average pipe radiator is more efficient than the cast iron sectional radiator.



Fig. 37.

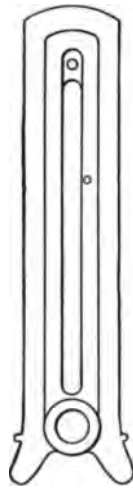


Fig. 38.

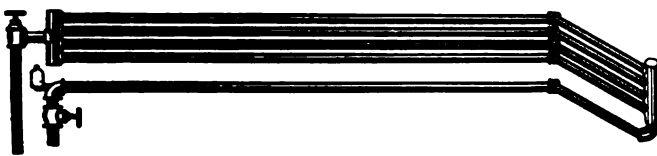


Fig. 39.

Circulation Coils. These are usually made up of 1 or 1½-inch wrought iron pipe, and may be hung on the walls of a room by means of hook plates or suspended overhead on hangers and rolls.

Fig. 39 shows a common form for schoolhouse and similar

work; this coil is usually made of $1\frac{1}{4}$ -inch pipe screwed into "headers" or "branch tees" at the ends, and is hung on the wall just below the windows. This is known as a "branch coil." Fig. 40 shows a "trombone coil," which is commonly used when the pipes cannot turn a corner, and where the entire coil must be placed upon one side of the room. Fig. 41 is called a "miter coil," and is used under the same conditions as a trombone coil if



Fig. 40.

there is room for the vertical portion. This form is not as pleasing in appearance as either of the other two and is only found in factories or shops where looks are of minor importance.

Overhead coils are usually of the "miter" form laid on the side and suspended about a foot from the ceiling; they are less efficient than when placed nearer the floor, as the warm air stays at the ceiling and the lower part of the room is likely to remain cold. They are only used when wall coils or radiators would be in the way of fixtures or when they would come below the water

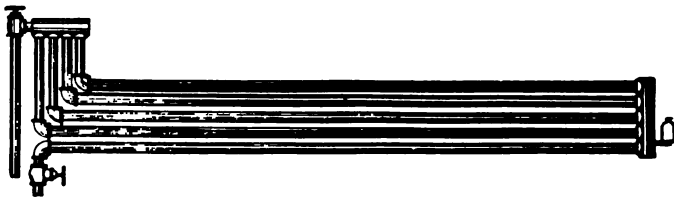


Fig. 41.

line of the boiler if placed near the floor. A coil should never be made up as shown in Fig. 42, as unequal expansion of the pipes would cause strains which would soon result in leaky joints. When steam is first turned on a coil it usually passes through a portion of the pipes first and heats them while the others remain cold and full of air. Therefore the coil must always be made up in such a way that each pipe shall have a certain amount of spring and may expand independently without bringing undue strains upon

the others. Circulation coils should incline about 1 inch in 20 feet toward the return end in order to secure proper drainage and quietness of operation.

Efficiency of Radiators. The efficiency of a radiator, that is, the B. T. U. which it gives off per square foot of surface per hour, depends upon the difference in temperature between the steam in the radiator and the surrounding air, the velocity of the air over the radiator, and the quality of the surface, whether smooth or rough. In ordinary low-pressure heating the first condition is practically constant, but the second varies somewhat with the pattern of the radiator. An open design which allows the air to circulate freely over the radiating surfaces is more efficient than a close pattern and for this reason a pipe coil is more efficient than a radiator.

In a large number of tests of cast iron radiators, working

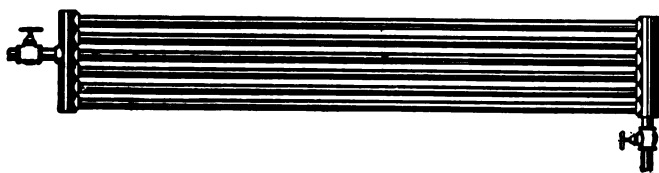


Fig. 42.

under usual conditions, the heat given off per square foot of surface per hour, for each degree difference in temperature between the steam and surrounding air, was found to vary from about 1.3 to 1.7 B. T. U. The temperature of steam at 3 pounds pressure is 220 degrees, and $220 - 70 = 150$, which may be taken as the average difference between the temperature of the steam and the air of the room, in ordinary low-pressure work. If we take the mean of the above results, that is, 1.5 we shall have $150 \times 1.5 = 225$ B. T. U. as the efficiency of an average cast iron radiator. A circulation coil made up of pipes from 1 to 2 inches in diameter will easily give off 300 B. T. U. under the same conditions, and a shallow pipe radiator of standard height may be safely counted upon to give 260. These efficiencies are lower than are given by some engineers, but if the sizes are taken from trade catalogues it is not safe to go much above these figures. If the radiator is to be used for warming rooms which are to be kept at a temperature

above or below 70 degrees, the radiating surface may be changed in the same proportion as the difference in temperature between the steam and the air.

For example — if a room is to be kept at a temperature of 60° the efficiency of the radiator becomes $\frac{16}{225} \times 225 = 240$; that is the efficiency varies directly as the difference in temperature between the steam and the air of the room. It is not customary to consider this unless the steam pressure should be raised to 10 or 15 pounds or the temperature of the rooms changed 15 or 20 degrees from the normal.

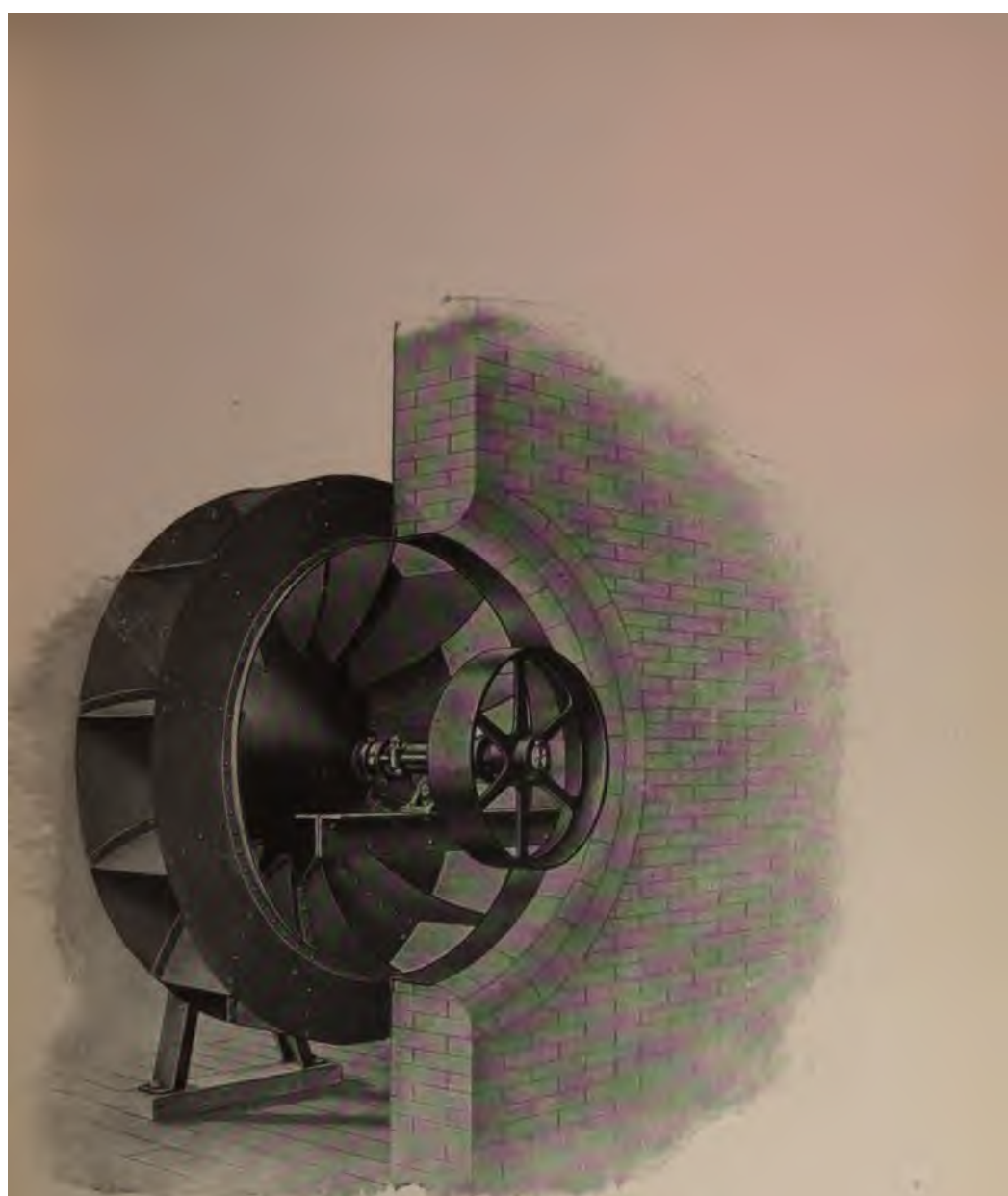
From the above it is easy to compute the size of radiator for any given room. First compute the heat loss per hour by radiation and conduction, in the coldest weather, then divide the result by 225 for cast iron radiators, 260 for pipe radiators and 300 for pipe coils. It is customary to make the radiators of such size, that they will warm the rooms to 70 degrees in the coldest weather. This varies a good deal in different localities, even in the same state, and the lowest temperature for which we wish to provide must be settled upon before any calculations are made. In New England and through the Middle and Western States it is usual to figure on warming a building to 70 degrees when the outside temperature is from zero to 10 degrees below.

The makers of radiators publish in their catalogues, tables giving the square feet of heating surface for different styles and heights, and these can be used in determining the number of sections required for all special cases.

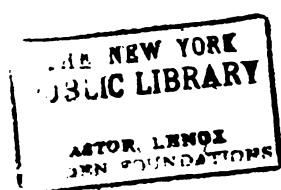
If pipe coils are to be used, it becomes necessary to reduce square feet of heating surface to linear feet of pipe; this can be done by means of the factors given below.

$$\text{Square feet of heating surface} \times \begin{cases} 3 & = \text{linear ft. of } 1'' \text{ pipe} \\ 2.3 & = \text{ " " } 1\frac{1}{2}'' \text{ " } \\ 2 & = \text{ " " } 1\frac{3}{4}'' \text{ " } \\ 1.6 & = \text{ " " } 2'' \text{ " } \end{cases}$$

The size of radiator is only made sufficient to keep the room warm after it is once heated, and no allowance is made for "warming up," that is, the heat given off by the radiator is just equal to that lost through walls and windows. This condition is offset in two ways — first, when the room is cold, the difference



CONE EXHAUST FAN, INLET SIDE.
American Blower Co.



in temperature between the steam and air of the room is greater and the radiator is more efficient, and second the radiator is proportioned for the coldest weather so that for a greater part of the time it is larger than necessary. This last condition is one of the disadvantages of direct steam heating; if steam is on the radiator

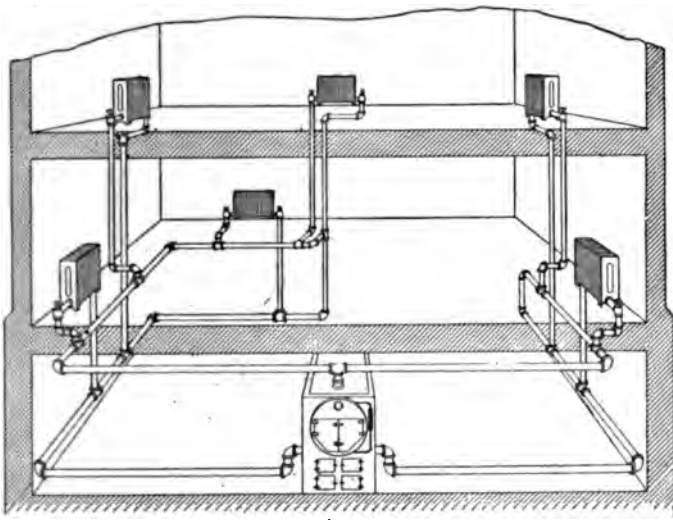


Fig. 43.

at all it will give off the same amount of heat regardless of the outside temperature.

Example.—A schoolroom is to be warmed with circulation coils of $1\frac{1}{4}$ -inch pipe. The heat loss is 30,000 B. T. U. per hour; what length of pipe will be required?

The heating surface of a pipe coil will be

$$\frac{30,000}{300} = 100 \text{ square feet.}$$

Therefore we need

$$2.3 \times 100 = 230 \text{ linear feet of } 1\frac{1}{4}\text{-inch pipe.}$$

Location. Radiators should be placed in the coldest part of the room if possible, as under windows or near outside doors. In living rooms it is often desirable to keep the windows free, in which case the radiators may be placed at one side. Circulation coils are run along the outside walls of a room under the

windows. Sometimes the position of the radiators is decided by the necessary location of the pipe risers, so that a certain amount of judgment must be used in each special case as to the best arrangement to suit all requirements.

Systems of Piping. There are three distinct systems of piping, known as the "two-pipe system," the "one-pipe relief system," and the "one-pipe circuit system," with various modifications of each.

Fig. 43 shows the arrangement of piping and radiators in the two-pipe system. The steam main leads from the top of the boiler and the branches are carried along near the basement ceiling; risers are taken off from the supply branches and carried up to the

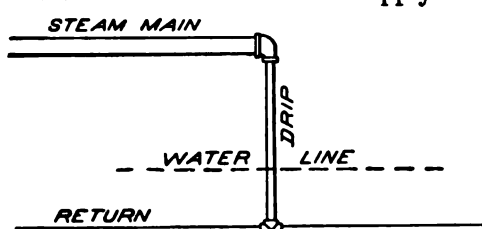


Fig. 44.

radiators on the different floors, and return pipes are brought down to the return mains, which should be placed near the basement floor below the water line of the boiler. Where the

building is more than two stories high, radiators in similar positions on different floors are connected with the same riser, which may run to the highest floor, and a corresponding return drop connecting with each radiator is carried down beside the riser to the basement. A system in which the main horizontal returns are below the water line of the boiler is said to have a "wet" or "sealed" return. If the returns are overhead and above the water line, it is called a "dry" return. Where the steam is exposed to extended surfaces of water, as in overhead returns, where the condensation partially fills the pipes, there is likely to be cracking or "water hammer" due to the sudden condensation of the steam as it comes in contact with the cooler water. This is especially noticeable when steam is first turned into cold pipes and radiators, and the condensation is excessive. When dry returns are used the pipes should be large, and have a good pitch toward the boiler.

In the case of sealed returns the only contact between the steam and standing water is in the vertical returns where the

exposed surfaces are very small (being equal to the sectional area of the pipes) and trouble from water hammer is practically done away with. Dry returns should be given an incline of at least 1 inch in 10 feet, while for wet returns 1 inch in 20 or even 40 feet is ample. The ends of all steam mains and branches should be dripped into the returns. If the return is sealed, the drip may be directly

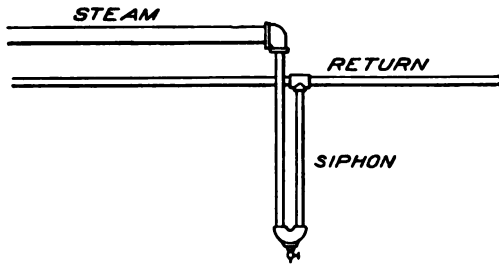


Fig. 45.

connected as shown in Fig. 44, but if it is dry, the connection should be provided with a siphon loop as indicated in Fig. 45. The loop becomes filled with water and prevents steam from

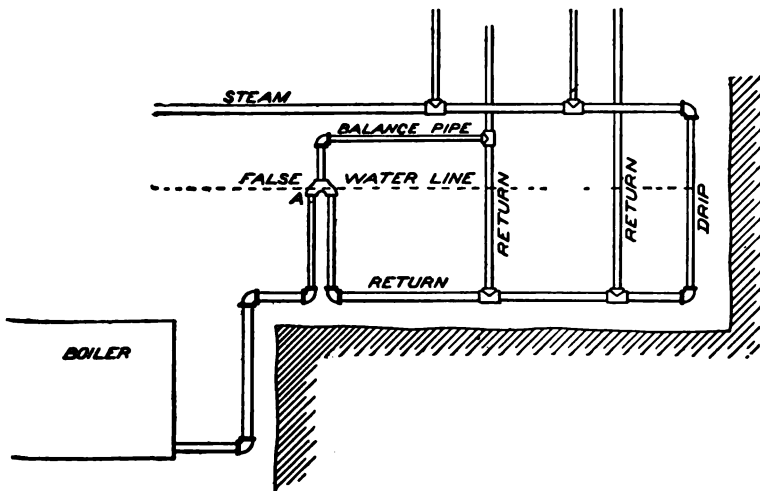


Fig. 46.

flowing directly into the return. As the condensation collects in the loop it overflows into the return pipe and is carried away. The return pipes in this case are of course filled with steam above the water, but it is steam which has passed through the radiators and their return connections, and is therefore at a slightly lower pressure, so that if steam were admitted directly from the

main it would tend to hold back the water in more distant returns and cause surging and cracking in the pipes. Sometimes the boiler is at a lower level than the basement in which the returns are run and it then becomes necessary to establish a "false" water line. This is done by making connections as shown in Fig. 46.

It is readily seen that the return water in order to reach the boiler must flow over the loop "A" which raises the water line, or seal, to the level shown by the dotted line. The balance pipe is to break the seal as the water flows over the loop, and prevent

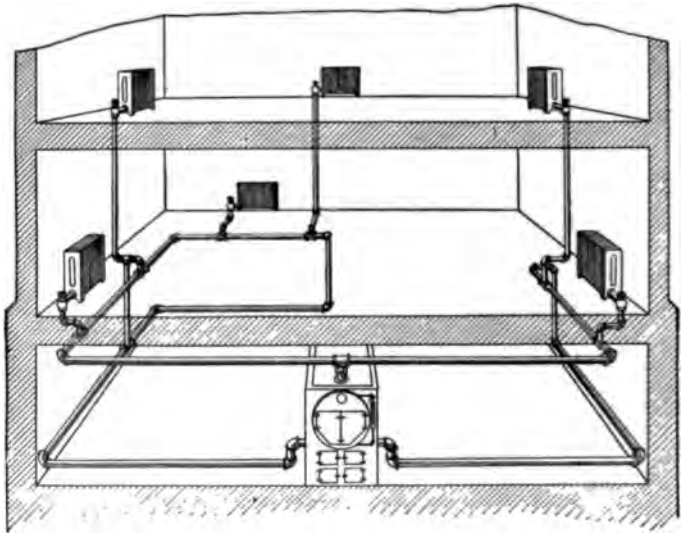


Fig. 47.

any siphon action which would tend to drain the water out of the return mains after a flow was once started.

One-Pipe Relief System. In this system of piping the radiators have but a single connection, the steam flowing in and the condensation draining out through the same pipe. Fig. 47 shows the method of running the pipes for this system. The steam main, as before, leads from the top of the boiler and is carried to as high a point as the basement ceiling will allow; it then slopes downward with a grade of about 1 inch in 10 feet and makes a circuit of the building or a portion of it.

Risers are taken off from the top and carried to the radiators above as in the two-pipe system, but in this case, the condensation

flows back through the same pipe and drains into the return main near the floor through drip connections which are made at frequent intervals. In a two-story building the bottom of each riser to the second floor is dripped, and in larger buildings it is customary to drip each riser that has more than one radiator connected with it. If the radiators are large and at a considerable distance from the next riser, it is better to make a drip connection for each radiator. When the return main is overhead, the risers should be dripped through siphon loops, but the ends of the branches should make direct connection with the returns. This is the reverse of the two-pipe system. In this case the lowest

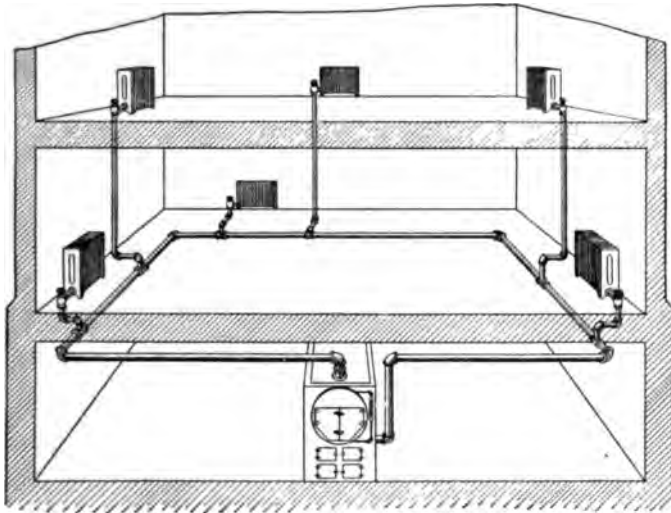


Fig. 48.

pressure is at the ends of the mains so that steam introduced into the returns at these points will cause no trouble in the pipes connecting between these and the boiler.

If no steam is allowed to enter the returns, a vacuum will be formed, and there will be no pressure to force the water back to the boiler. A check valve should always be placed in the main return near the boiler to prevent the water from flowing out in case of a vacuum being formed suddenly in the pipes.

One-Pipe Circuit System. (See Fig. 48.) In this case the steam main rises to the highest point of the basement as before,

and then with a considerable pitch makes an entire circuit of the building and again connects with the boiler below the water line. Single risers are taken from the top and the condensation drains back through the same pipes and is carried along with the flow of steam to the extreme end of the main, where it is returned to

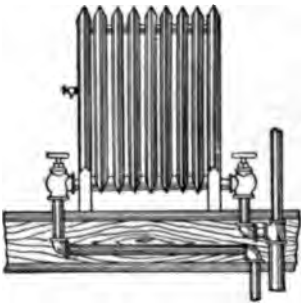


Fig. 49.

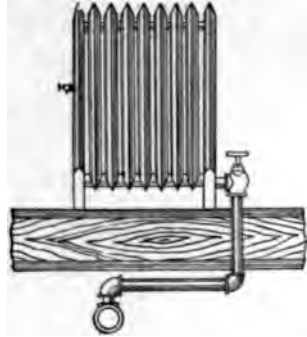


Fig. 50.

the boiler. The main is made large and of the same size throughout its entire length; it must be given a good pitch to insure satisfactory results.

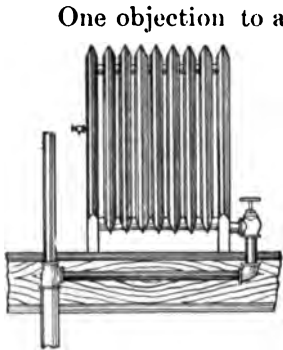


Fig. 51.

One objection to a single-pipe system is that the steam and return water are flowing in opposite directions, and the risers must be made of extra large size to prevent any interference. This is overcome in large buildings by carrying a single riser to the attic, large enough to supply the entire building; then branching and running "drops" to the basement. In this system the flow of steam is downward as well as that of water. This method of piping may be used with good results in two-pipe systems as well. Care must always be taken that no pockets or low points occur in any of the lines of pipe, but if for any reason they cannot be avoided they should be carefully drained.

Pipe Connections. Figs. 49, 50 and 51 show the common methods of making the connections between the supply pipes and

the radiators. Fig. 49 shows a two-pipe connection with a riser; the return is carried down to the main below. Fig. 50 shows a single pipe connection with a basement main and Fig. 51 a single connection with a riser.

Care must always be taken to make the horizontal part of the piping between the radiator and riser as short as possible and to give it a good pitch toward the riser. There are various ways of making these connections especially suited to different conditions,

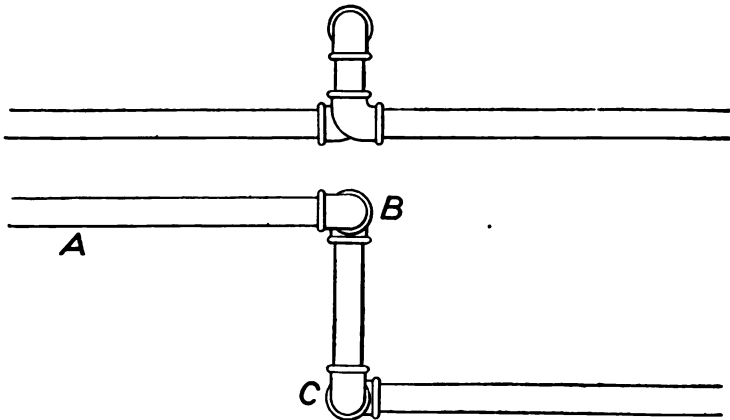


Fig. 52.

but the examples given serve to show the general principle to be followed.

Figs. 39, 40 and 41 show the common methods of making steam and return connections with circulation coils. The position of the air valve is shown in each case.

Expansion of Pipes. Cold steam pipes expand approximately 1 inch in each 100 feet in length when low pressure steam is turned into them, so that in laying out a system of piping we must arrange it in such a manner that there will be sufficient "spring" or "give" to the pipes to prevent injurious strains. This is done by means of offsets and bends. In the case of larger pipes this simple method will not be sufficient, and swivel or slip joints must be used, to take up the expansion. The method of making up a swivel joint is shown in Fig. 52.

Any lengthening of the pipe A will be taken up by slight turning or swivel movements at the points B and C. A slip joint

is shown in Fig. 53. The part *c* slides inside the shell *d* and is made steam tight by a stuffing box as shown. The pipes are connected at the flanges A and B.

When pipes pass through floors or partitions, the woodwork should be protected by galvanized iron sleeves having a diameter from $\frac{3}{4}$ to 1 inch greater than the pipe. Fig. 54 shows a form of

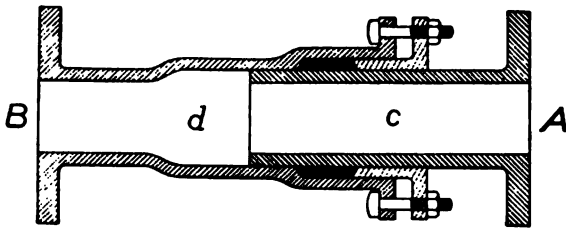


Fig. 53.

adjustable floor sleeve which may be lengthened or shortened to conform to the thickness of floor or partition. If plain sleeves are used, a plate should be placed around the pipe where it passes through the floor or partition. These are made in two parts so

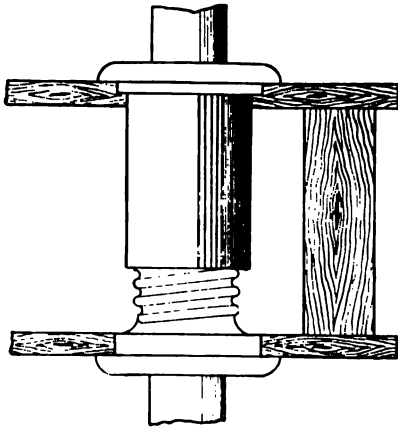


Fig. 54.

that they may be put in place after the pipe is hung. A plate of this kind is shown in Fig. 55.

Valves. The different styles commonly used for radiator connections are shown in Figs. 56, 57 and 58, and are known as "angle," "offset" and "corner" valves respectively. The first is used when the radiator is at the top of a riser or when the connections are like those shown in Figs. 49, 50 and 51; the second is

used when the connection between the riser and radiator is above the floor, and the third when the radiator has to be set close in the corner of a room and there is not space for the usual connection. A *globe* valve should never be used in a horizontal steam supply or dry return; the reason for this is plainly shown in

Fig. 59. In order for water to flow through the valve it must rise to a height shown by the dotted line, which would half fill the pipes, and cause serious trouble from water hammer. The gate valve shown in Fig. 60 does not have this undesirable feature, as the opening is on a level with the bottom of the pipe.

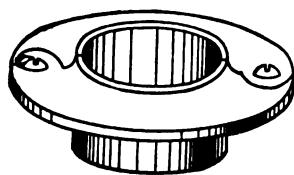


Fig. 55.

Air Valves. Valves of various kinds are used for freeing the radiators from air when steam is turned on. Fig. 61 shows simplest form, which is operated by hand.

Fig. 62 is a type of automatic valve; it consists of a shell, which is attached to the radiator. B is a small opening which may be closed by the spindle C which is provided with a conical end. D is a strip composed of a layer of iron or steel



Fig. 56.



Fig. 57.



Fig. 58.

and one of brass soldered or brazed together. The action of the valve is as follows; when the radiator is cold and filled with air the valve stands as shown in the cut. When steam is turned on, the air is driven out through the opening B. As soon as this is expelled and steam strikes the strip D, the two prongs spring

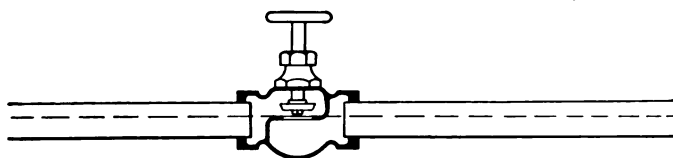


Fig 59.

apart owing to the unequal expansion of the two metals due to the heat of the steam. This raises the spindle C and closes the opening so that no steam can escape. If air should collect in the valve and the metal strip become cool it would contract and the spindle would drop and allow the air to escape through B as be-

fore. E is an adjusting nut and F is a float attached to the spindle, and is supposed in case of a sudden rush of water with the air to rise and close the opening; this action is somewhat uncertain, especially if the pressure of water continues for some time.

There are other types of valves acting on the same principle. The valve shown in Fig. 63 is closed by the expansion of a piece of vulcanite instead of a metal strip, and has no water float.

The valve shown in Fig. 64 acts on a somewhat different principle. The float C is made of thin brass, closed at top and bottom, and is partially filled with wood alcohol. When steam strikes the float the alcohol is vaporized, and creates a pressure sufficient to bulge out the ends slightly which raises the spindle and closes the opening B. Fig. 65 shows a form of so-called "vacuum valve." It acts in a similar manner to those already described, but has in addition a ball check which prevents the air from being drawn into the radiator, should the steam go down and a vacuum be formed. If a partial vacuum exists in the

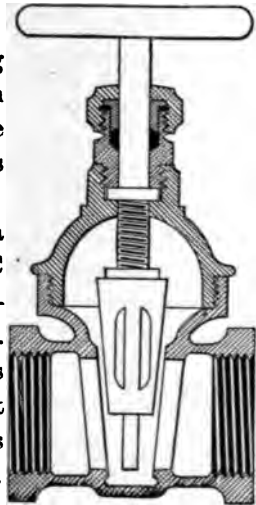


Fig. 60.

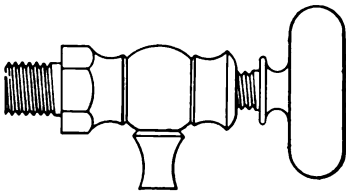


Fig. 61.

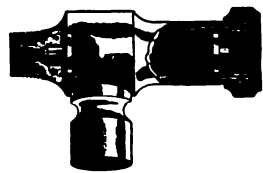


Fig. 63.

boiler and radiators, the boiling point, and consequently the temperature of the steam are lowered, and less heat is given off by the radiators. This method of operating a heating plant is sometimes advocated for spring and fall when less heat is required, and steam under pressure would overheat the rooms.

Pipe Sizes. The proportioning of the steam pipes in a heating plant is of the greatest importance, and should be carefully worked out by methods which experience has proved to be correct.

There are several ways of doing this, but for ordinary conditions the following tables have given excellent results in actual practice. They have been computed from what is known as

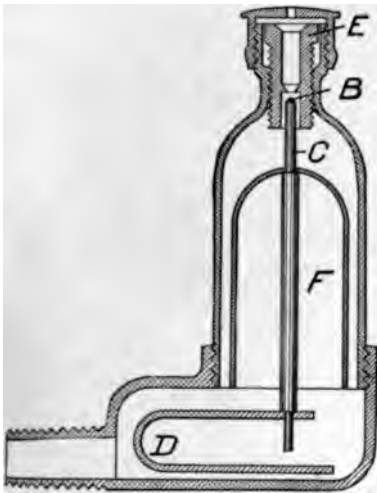


Fig. 62.

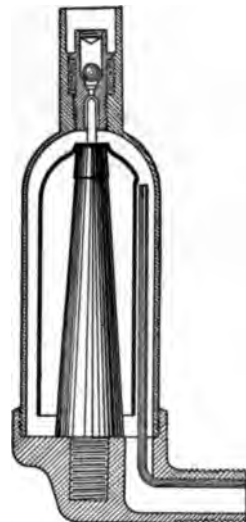


Fig. 65.

D'Arcy's formula, with suitable corrections made for actual working conditions. As the computations are somewhat complicated, only the results will be given here, with full directions for their proper use. The following table gives the flow of steam in pounds per minute for pipes of different diameters, and with varying drops in pressure between the supply and discharge ends of the pipe. These quantities are for pipes 100 feet in length; for other lengths the results must be corrected by the factors given in table XII. As the length of the pipe increases, the friction becomes greater, and the quantity of steam discharged in a given time is diminished.

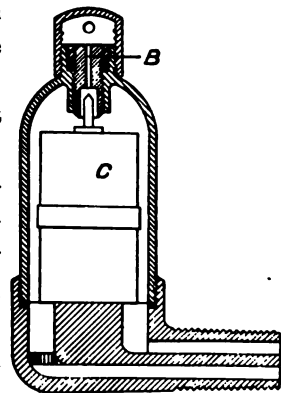


Fig. 64.

Table X is computed on the assumption that the drop in pressure between the two ends of the pipe equals the initial pressure. If the drop in pressure is less than the initial pressure the

actual discharge will be slightly greater than the quantities given in the table, but this difference will be small for pressures up to 5 pounds, and can be neglected as it is on the side of safety. For higher initial pressures, table XI has been prepared. This is to

TABLE X.

Diam. of Pipe.	Drop in Pressure (Pounds.)								
	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1½	2	3	4	5
1	.44	.63	.78	.91	1.13	1.31	1.66	1.97	2.26
1¼	.81	1.16	1.43	1.66	2.05	2.39	3.02	3.59	4.12
1½	1.06	1.89	2.34	2.71	3.36	3.92	4.94	5.88	6.75
2	2.93	4.17	5.16	5.99	7.43	8.65	10.9	13.0	14.9
2½	5.29	7.52	9.32	10.8	13.4	15.6	19.7	23.4	26.9
3	8.61	12.3	15.2	17.6	21.8	25.4	32	31.8	43.7
3½	12.9	18.3	22.6	26.3	32.5	37.9	47.8	56.9	65.3
4	18.1	25.7	31.8	36.9	45.8	53.3	67.2	80.1	91.9
5	32.2	45.7	56.6	65.7	81.3	94.7	120	142	163
6	51.7	73.3	90.9	106	131	152	192	229	262
7	76.7	109	135	157	194	226	285	339	390
8	108	154	190	222	274	319	402	478	549
9	147	209	258	299	371	432	545	649	745
10	192	273	339	393	487	567	715	852	977
12	305	434	537	623	771	899	1130	1350	1550
15	535	761	942	1090	1350	1580	1990	2370	2720

be used in connection with table X as follows. First find from table X the quantity of steam which will be discharged through the given diameter of pipe with the assumed drop in pressure ;

TABLE XI.

Drop in Pressure in Pounds.	Initial Pressure.					
	10	20	30	40	60	80
1	1.27	1.49	1.68	1.84	2.13	2.38
1½	1.26	1.48	1.66	1.83	2.11	2.36
2	1.24	1.46	1.64	1.80	2.08	2.32
3	1.21	1.41	1.59	1.75	2.02	2.26
4	1.17	1.37	1.55	1.70	1.97	2.20
5	1.14	1.34	1.51	1.66	1.92	2.14
6	1.12	1.31	1.47	1.62	1.87	2.09

then look in table XI for the factor corresponding with the assumed drop and the higher initial pressure to be used. The quantity given in table X multiplied by this factor will give the actual capacity of the pipe under the given conditions.

Example—What weight of steam will be discharged through a 3" pipe, 100 feet long, with an initial pressure of 60 pounds and a drop of 2 pounds?

Looking in table X we find that a 3" pipe will discharge 25.4 pounds of steam per minute with a 2-pound drop. Then looking in table XI we find the factor corresponding to 60 pounds initial pressure and a drop of 2 pounds to be 2.02. Then according to the rule given, $25.4 \times 2.02 = 51.3$ pounds which is the capacity of a 3" pipe under the assumed conditions.

Sometimes the problem will be presented in the following way: What size of pipe will be required to deliver 80 pounds of steam a distance of 100 feet with an initial pressure of 40 pounds and a drop of 3 pounds?

TABLE XII.

Feet.	Factor.	Feet.	Factor.	Feet.	Factor.	Feet.	Factor.
10	3.16	120	.91	275	.60	600	.40
20	2.24	130	.87	300	.57	650	.39
30	1.82	140	.84	325	.55	700	.37
40	1.58	150	.81	350	.53	750	.36
50	1.41	160	.79	375	.51	800	.35
60	1.29	170	.76	400	.50	850	.34
70	1.20	180	.74	425	.48	900	.33
80	1.12	190	.72	450	.47	950	.32
90	1.05	200	.70	475	.46	1,000	.31
100	1.00	225	.66	500	.45		
110	.95	250	.63	550	.42		

We have seen that the higher the initial pressure with a given drop, the greater will be the quantity of steam discharged; therefore a smaller pipe will be required to deliver 80 pounds of steam at 40 pounds than at 3 pounds initial pressure. From table XI we find that a given pipe will discharge 1.7 times as much steam per minute with a pressure of 40 pounds, and a drop of 3 pounds, as it would with a pressure of 3 pounds, dropping to zero. From this it is evident that if we divide 80 by 1.7 and look in table X under "3 pounds drop" for the result thus obtained, the size of pipe corresponding will be that required.

$$80 \div 1.7 = 47.$$

The nearest number in the table marked "3 pounds drop" is 47.8 which corresponds to a $3\frac{1}{2}$ " pipe and is the size required.

These conditions will seldom be met with in low-pressure heating, but apply more particularly to combination power and heating plants, and will be taken up more fully under that head. For lengths of pipe other than 100 feet, multiply the quantities given in table X by the factors found in table XII.

Example — What weight of steam will be discharged per minute through a $3\frac{1}{2}$ " pipe, 450 feet long with a pressure of 5 pounds and a drop of $\frac{1}{2}$ pound?

Table X, which may be used for all pressures below 10 pounds, gives for a $3\frac{1}{2}$ " pipe, 100 feet long, a capacity of 18.3 pounds for the above conditions. Looking in table XII, we find the correction factor for 450 feet to be .47. Then $18.3 \times .47 = 8.6$ pounds, the quantity of steam which will be discharged if the pipe is 450 feet long.

Examples involving the use of tables X, XI and XII in combination are quite common in practice. The following shows the method of calculation:

What size of pipe will be required to deliver 90 pounds of steam per minute a distance of 800 feet, with an initial pressure of 80 pounds and a drop of 5 pounds? Table XII gives the factor for 800 feet as .35 and table XI that for 80 pounds pressure and 5 pounds drop as 2.09. Then $\frac{90}{.35 \times 2.09} = 123$; which is the equivalent quantity, we must look for in table X. We find that a 4" pipe will discharge 91.9 pounds, and a 5" pipe 163 pounds. A $4\frac{1}{2}$ " pipe is not commonly carried in stock and we should probably use a 5" in this case, unless it was decided to use a 4" and allow a slightly greater drop in pressure. In ordinary heating work with pressures varying from 2 to 5 pounds, a drop of $\frac{1}{4}$ pound in 100 feet has been found to give satisfactory results.

In computing the pipe sizes for a heating system by the above methods it would be a long process to work out the size of each branch use separately so the following table has been prepared for ready use in low-pressure work.

As most direct heating systems, and especially those in schoolhouses, are made up of both radiators and circulation coils,

an efficiency of 300 B. T. U. has been taken for direct radiation of whatever variety, no distinction being made between the different kinds. This gives a slightly larger pipe than is necessary for cast iron radiators, but it is probably offset by bends in the pipes, and in any case gives a slight factor of safety. We find from a steam table that the "latent heat" of steam at 20 pounds above a vacuum, (which corresponds to 5 pounds gage-pressure) is $954 +$ B. T. U., which means that for every pound of steam condensed in a radiator 954 B. T. U. are given off for warming the air of the room. If a radiator has an efficiency of 300 B. T. U., then each square foot of surface will condense $300 \div 954 = .314$ pounds of steam per hour, so that we may assume in round numbers a condensation of $\frac{1}{3}$ of a pound of steam per hour for each square foot of direct radiation, when computing the sizes of steam pipes in low-pressure heating. Table XIII has been calculated on this assumption, and gives the square feet of heating surface

TABLE XIII.

LENGTH OF PIPE 100 FEET.

Size of Pipe.	Square Feet of Heating Surface.	
	$\frac{1}{2}$ Pound Drop.	$\frac{1}{3}$ Pound Drop.
1	80	114
$1\frac{1}{4}$	145	210
$1\frac{1}{2}$	190	340
2	525	750
$2\frac{1}{2}$	950	1350
3	1550	2210
$3\frac{1}{2}$	2320	3290
4	3250	4620
5	5800	8220
6	9320	13200
7	13800	19620
8	19440	27720

which different sizes of pipe will supply, with drops in pressure of $\frac{1}{4}$ and $\frac{1}{3}$ pounds, in each 100 feet of pipe. The former should be used for pressures from 1 to 5 pounds, and the latter may be used for pressures over 5 pounds, under ordinary conditions. The

sizes of long mains and special pipes of large size should be proportioned directly from tables X, XI and XII.

Where the two-pipe system is used and the radiators have separate supply and return pipes, the risers or vertical pipes may be taken from table XIII, but if the single pipe system is used, the risers must be increased in size as the steam and water are flowing in opposite directions and must have plenty of room to pass each other. It is customary in this case to base the computation on the velocity of the steam in the pipes rather than on the drop in pressure. Assuming as before, a condensation of one-third of a pound of steam per hour per square foot of radiation, the following tables have been prepared for velocities of 10 and 15 feet per second. The sizes given in table XV have been found sufficient in most cases, but the larger sizes, based on a flow of 10 feet per second, give greater safety and should be more generally used. The size of the largest riser should usually be limited to 2½" in school and dwelling house work unless it is a special pipe carried up in a concealed position. If the length of riser is short between the lowest radiator and the main, a higher velocity of 20 feet or more may be allowed through this portion rather than make the pipe excessively large.

TABLE XIV.

TABLE XV.

10 Feet Per Second Velocity.		15 Feet Per Second Velocity.	
Size of Pipe.	Sq Feet of Radiation.	Size of Pipe.	Sq. Feet of Radiation.
1	30	1	50
1½	60	1½	90
1½	80	1½	120
2	130	2	200
2½	190	2½	290
3	290	3	340
3½	390	3½	590

Example.- Compute the size of pipe required to supply 10,000 square feet of direct radiation, where the distance to the boiler house is 300 feet and the pressure carried is 10 pounds; allowing a drop in pressure of 4 pounds.





A BATTERY OF IDEAL STEAM BOILERS SHOWING METHOD OF YOKING THE
MAIN SUPPLY AND RETURN PIPE.

Steam required $= \frac{1}{8} \times 10,000 = 3333$ pounds per hour
 $= 55.6$ pounds per minute.

From Table XII we see that this corresponds to $55.6 \div .57 = 97.5$ pounds for a pipe 100 feet long. From Table XI the discharge factor is 1.14. Hence in Table X we look for $\frac{97.5}{1.14} = 85.5$ under 4 pounds drop, and we find that a 5-inch pipe must be used.

Dia. of Steam Pipe.	Dia. of Dry Return.	Dia. of Sealed Return.
1	1	$\frac{3}{4}$
$1\frac{1}{4}$	1	$\frac{1}{2}$
$1\frac{1}{2}$	$1\frac{1}{4}$	1
2	$1\frac{1}{2}$	$1\frac{1}{4}$
$2\frac{1}{2}$	2	$1\frac{1}{2}$
3	$2\frac{1}{2}$	2
$3\frac{1}{2}$	$2\frac{1}{2}$	2
4	3	$2\frac{1}{2}$
5	3	$2\frac{1}{2}$
6	$3\frac{1}{2}$	3
7	$3\frac{1}{2}$	3
8	4	$3\frac{1}{2}$
9	5	$3\frac{1}{2}$
10	5	4
12	6	5

Returns. The size of return pipes is usually a matter of custom and judgment rather than computation. It is a common rule among steam fitters to make the returns one size smaller than the corresponding steam pipes. This is a good rule for the smaller sizes, but gives a larger return than is necessary for the larger sizes of pipe. Table XVI gives different sizes of steam pipes with the corresponding diameters for dry and sealed returns.

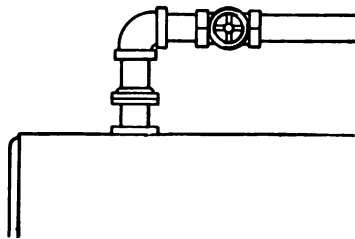


Fig. 66.

The length of run and number of turns in a return pipe should be noted and any unusual conditions provided for. Where the condensation is discharged through a trap into a lower pressure the sizes given may be slightly reduced, especially among the larger sizes, depending upon the difference in pressures.

Radiators are usually tapped for pipe connections as follows, and these sizes may be used for the connections with the mains or risers.

TWO-PIPE CONNECTION.

Square Feet of Radiation.	Steam.	Return.
10 to 30	$\frac{3}{4}$ "	$\frac{3}{4}$ "
30 to 48	1 "	$\frac{3}{4}$ "
48 to 96	$1\frac{1}{4}$ "	1 "
96 to 150	$1\frac{1}{2}$ "	$1\frac{1}{4}$ "

SINGLE PIPE CONNECTION.

10 to 24	1 "
24 to 60	$1\frac{1}{4}$ "
60 to 80	$1\frac{1}{2}$ "
80 to 130	2 "

Boiler Connections. The steam main should be connected to the rear nozzle, if a tubular boiler is used, as the boiling of the water is less violent at this point and dryer steam will be obtained. The shut-off valve should be placed in such a position that pockets for the accumulation of condensation will be avoided. Fig. 66 shows a good position for the valve.

The return connection is made through the blow-off pipe and should be arranged so that the boiler can be blown off without draining the returns. A check valve should be placed in the main return and a plug cock in the blow-off pipe. Fig. 67 shows in plan a good arrangement for these connections.

Blow-Off Tank. Where the blow-off pipe connects with a sewer some means must be provided for cooling the water or the expansion and contraction caused by the hot water flowing through the drain pipes will start the joints and cause leaks. For this reason it is customary to pass the water through a blow-off tank. A form of wrought iron tank is shown in Fig. 68. It

consists of a receiver supported on cast-iron cradles. The tank ordinarily stands nearly full of cold water.

The pipe from the boiler enters above the water line, and the sewer connection leads from near the bottom as shown. A vapor pipe is carried from the top of the tank above the roof of the building. When water from the boiler is blown into the tank

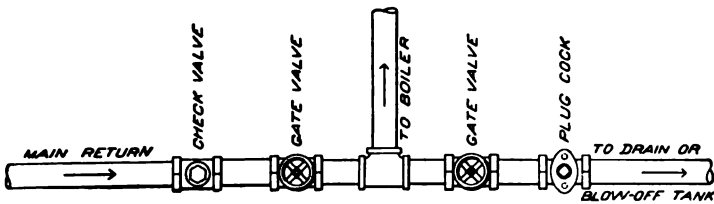


Fig. 67.

cold water from the bottom flows into the sewer and the steam is carried off through the vapor pipe. The equalizing pipe is to prevent any siphon action which might draw the water out of the tank after a flow was once started. As only a part of the water is blown out of a boiler at one time the blow-off tank can be of a comparatively small size. A tank 24" $\times$ 48" should be large

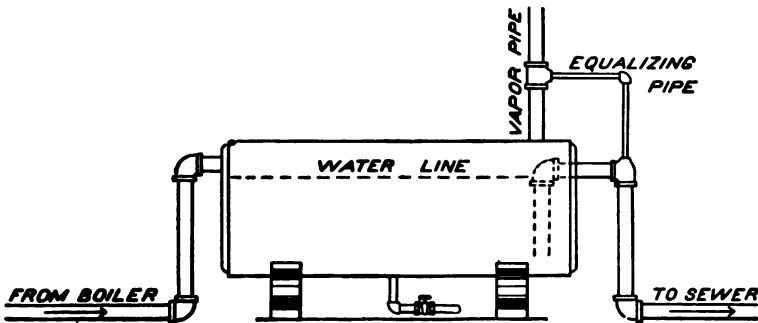
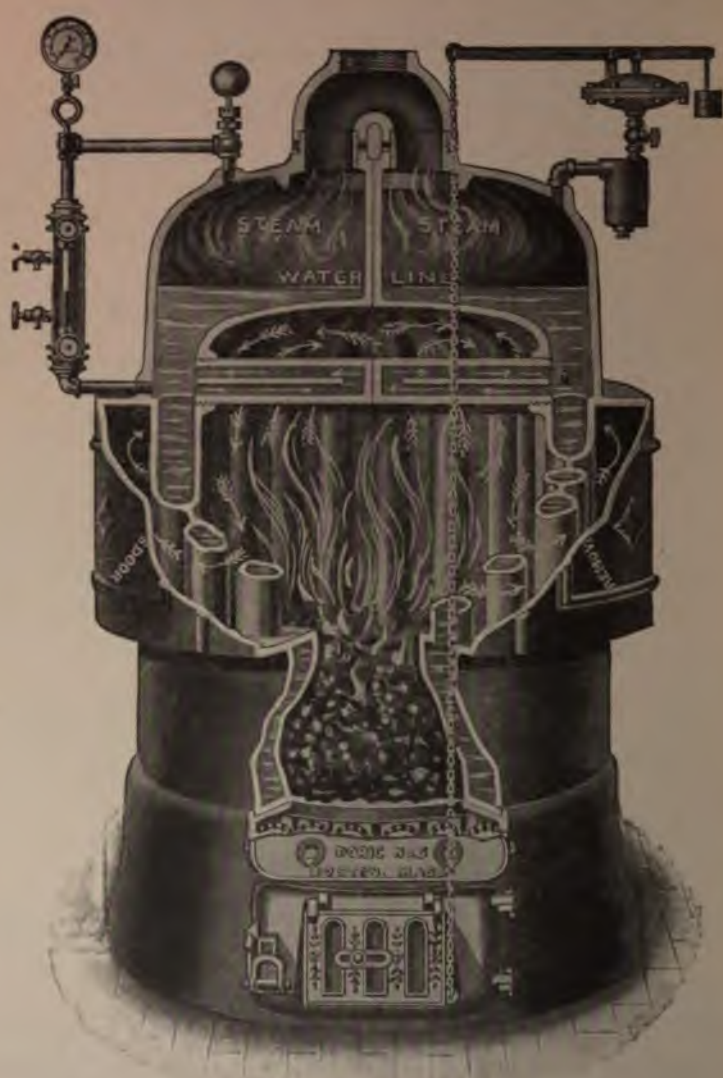


Fig. 68.

enough for boilers up to 48 inches in diameter and one 36" $\times$ 72" should care for a boiler 72 inches in diameter. If smaller quantities of water are blown off at a time smaller tanks can be used. The sizes given above are sufficient for batteries of 2 or more boilers, as one boiler can be blown off and the water allowed to cool before a second one is blown off. Cast iron tanks are often used in place of wrought iron and these may be sunken in the ground if desired.



Cast Iron Seamless Tubular Steam Heater.

HEATING AND VENTILATION.

PART II.

INDIRECT STEAM HEATING.

Types of Heaters. Various forms of indirect radiators have been shown in Figs. 8, 9, 14 and 15 of Part I. A hot-water radiator may be used for steam but a steam radiator cannot always be used for hot water as it must be especially designed to produce a continuous flow of water through it from top to bottom. Figs. 1 and



Fig. 1.

2 show the outside and the interior construction of a common pattern of indirect radiator designed especially for steam. The arrows in Fig. 2 indicate the path of the steam through the



Fig. 2.

radiator which is supplied at the right while the return connection is at the left. The air valve in this case should be connected in the end of the last section near the return.

A very efficient form of radiator and one that is especially adapted to the warming of large volumes of air as in schoolhouse

work, is shown in Fig. 3, and is known as the "School pin" radiator. This can be used for either steam or hot water as there is a continuous passage downward from the supply connection at the top to the return at the bottom. These sections or slabs are made up in stacks after the manner shown in Fig. 4 which repre-



Fig. 3.

sents an end view of several sections connected together with special nipples.

A very efficient form of indirect heater may be made up of wrought iron pipe joined together with branch tees and return bends. A heater like that shown in Fig. 5 is known as a "box coil." Its efficiency is increased if the pipes are "staggered," that is, if the pipes in alternate rows are placed over the spaces between those in the row below.

Stacks and Casings. It has already been stated that a group of sections connected together is called a stack, and ex-

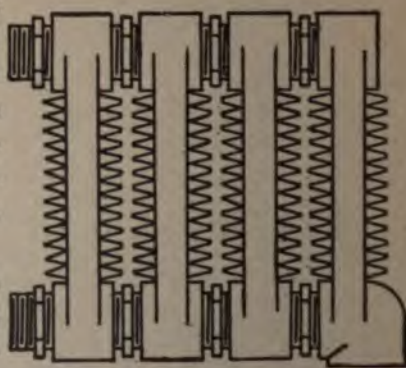


Fig. 4.

amples of these with their casings are shown in Figs. 6 and 7 of Part I. The casings are usually made of galvanized iron and are made up in sections by means of small bolts so that they may be taken apart in case it is necessary to make repairs. Large stacks are often enclosed in brick work; the sides consisting of 8-inch walls and the top being covered over with a layer of brick and mortar

supported on light wrought iron tee bars. Where a single stack supplies several flues or registers the connections between these and the warm-air chamber are made in the same manner as already described for furnace heating. When galvanized iron casings are used the heater is supported by hangers from the floor above. Fig. 6 shows the method of hanging a heater from a wooden

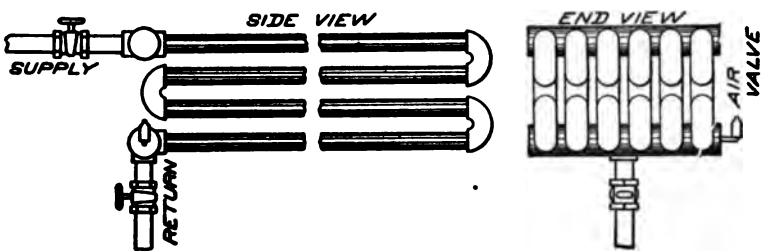


Fig. 5.

floor. If the floor is of fireproof construction the hangers may pass up through the brickwork and the ends be provided with nuts and large washers or plates; or they can be clamped to the iron beams which carry the floor. Where brick casings are used, the heaters are supported upon pieces of pipe or light I-beams built into the walls.

Dampers. The general arrangement of a galvanized iron casing and mixing damper is

shown in Fig. 7. The cold-air duct is brought along the basement ceiling from the inlet window and connects with the cold-air chamber beneath the heater. The entering air passes up between the sections and rises through the register above, as shown by the arrows. When the mixing damper is in its lowest position all air reaching the register must pass through the heater, but if the damper is raised to the position shown, part of the air will pass by without going through the heater and the mixture entering through the register will be at a lower temperature than before. By changing the position of the damper the proportions of warm and cold air delivered to the

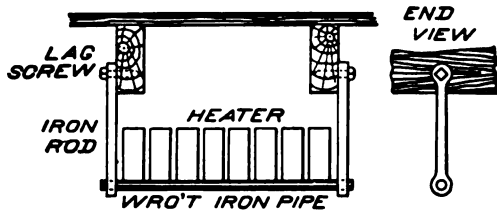


Fig. 6.

room can be varied, thus regulating the temperature without diminishing, to any great extent, the quantity of air delivered. The objection to this form of damper is that there is a tendency

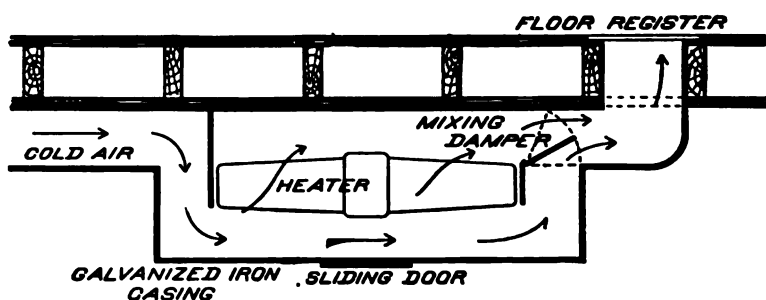


Fig. 7.

for the air to enter the room before it is thoroughly mixed, that is, a stream of warm air will rise through one half of the register while cold air enters through the other. This is especially true if

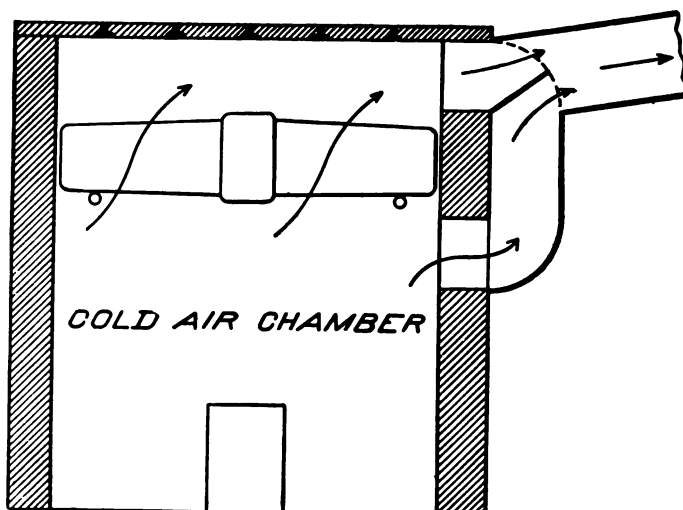


Fig. 8.

the connection between the damper and register is short. Fig. 8 shows a similar heater and mixing damper, with brick casing. Cold air is admitted to the large chamber below the heater and

rises through the sections to the register as before. The action of the mixing damper is the same as already described. Several flues or registers may be connected with a stack of this form, each connection having its own mixing damper.

The arrangement shown in Fig. 9 is somewhat different and overcomes the objection noted in connection with Fig. 7 by sub-

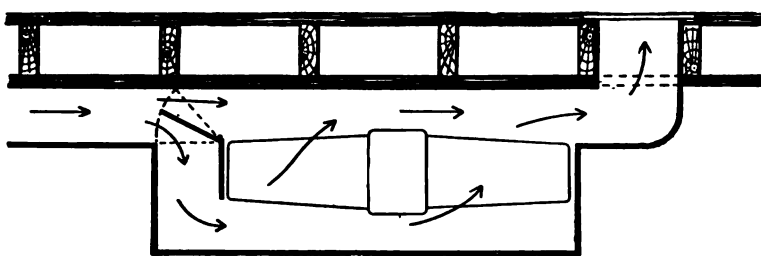


Fig. 9.

stituting another. The mixing damper in this case is placed at the other end of the heater. When it is in its highest position all of the air must pass through the heater before reaching the register, but when partially lowered a part of the air passes over the heater and the result is a mixture of cold and warm air, in proportions depending upon the position of the damper. As the layer of warm air in this case is below the cold air, it tends to rise through it, and a more thorough mixture is obtained than is possible with the damper shown in Fig. 8. One quite serious objection however to this form of damper is illustrated in Fig. 10.

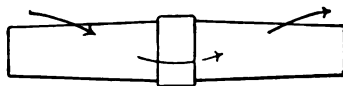


Fig. 10.

When the damper is nearly closed so that the greater part of the air enters above the heater, it has a tendency to fall between the sections, as shown by the arrows, and becoming heated rises again, so that it is impossible to deliver air to a room below a certain temperature. This peculiar action increases as the quantity of air admitted below the heater is diminished. When the inlet register is placed in the wall at some distance above the floor, as in schoolhouse work, a thorough mixture of air can be obtained by placing the heater so that the current of warm air will pass up the front of the flue and be discharged into the room through the

lower part of the register. This is shown quite clearly in Fig. 11 where the current of warm air is represented by crooked arrows and the cold air by straight arrows. The two currents pass up the flue separately, but as soon as they are discharged through the register the warm air tends to rise, and the cold air to fall, with the result of a more or less complete mixture as shown.

It is often desirable to warm a room at times when ventilation

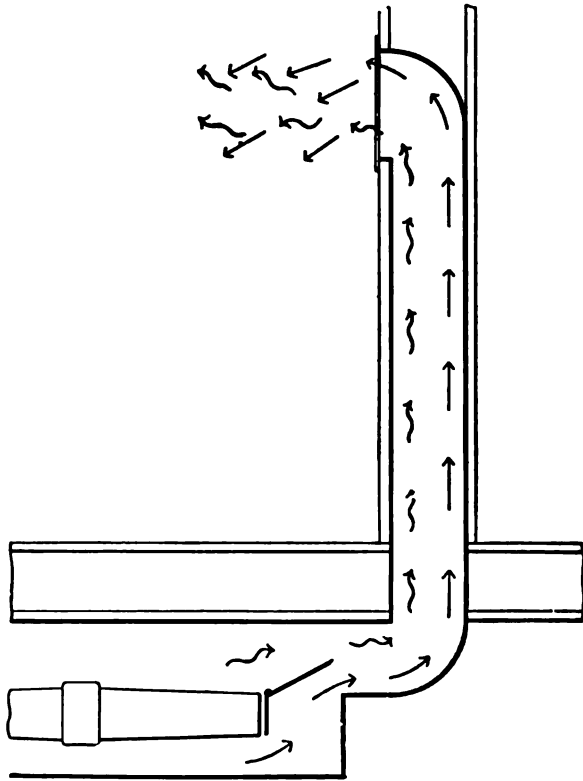


Fig. 11.

is not necessary, as in the case of living rooms during the night, or for quick warming in the morning. A register and damper for air rotation should be provided in this case. Fig. 12 shows an arrangement for this purpose. When the damper is in the position shown, air will be taken from the room above and be warmed over and over, but by raising the damper, the supply will be taken

from outside. Special care should be taken to make all mixing dampers tight against air leakage, else their advantages will be lost. They should work easily and close tightly against flanges covered with felt. They may be operated from the rooms above by means of chains passing over guide pulleys; special attachments should be provided for holding in any desired position.

Size of Heaters. The efficiency of an indirect heater depends upon its form, the difference in temperature between the steam and the surrounding air, and the velocity with which the air passes over the heater. Under ordinary conditions in dwelling-house work, a good form of indirect radiator will give off about 2 B. T. U. per square foot per hour for each degree difference in temperature. Assuming a steam pressure of 2 pounds and an outside temperature of zero we should have a difference in tem-

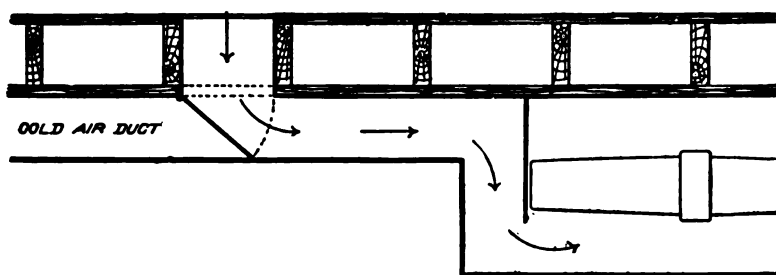


Fig. 12.

perature of about 220 degrees, which under the conditions stated would give an efficiency of $220 \times 2 = 440$ B. T. U. per hour for each square foot of radiation. By making a similar computation for 10 degrees below zero we find the efficiency to be 460. In the same manner we may calculate the efficiency for varying conditions of steam pressure and outside temperature. In the case of schoolhouses and similar buildings where large volumes of air are warmed to a moderate temperature, a somewhat higher efficiency is obtained due to the increased velocity of the air over the heaters. Where efficiencies of 440 and 460 are used for dwellings, we may substitute 600 and 620 for school-houses. This corresponds approximately to 2.7 B. T. U. per square foot per hour for a difference of 1 degree between the air and steam.

The principles involved in indirect steam heating are similar

to those already described in furnace heating. Part of the heat given off by the radiator must be used in warming up the air supply to the temperature of the room, and part for offsetting the loss by conduction through walls and windows. The method of computing the heating surface required, depends upon the volume of air to be supplied to the room. In the case of a schoolroom or hall, where the air quantity is large as compared with the exposed wall and window surface we should proceed as follows:

First compute the B. T. U. required for loss by conduction through walls and windows, and to this add the B. T. U. required for the necessary ventilation, and divide the sum by the efficiency of the radiators. An example will make this clear.

How many square feet of indirect radiation will be required to warm and ventilate a schoolroom in zero weather, where the heat loss by conduction through walls and windows is 36000 B. T. U. and the air supply is 100,000 cubic feet per hour? By the methods given under "Heat for Ventilation" we have

$$\frac{100,000 \times 70}{55} = 127,272 =$$

B. T. U. required for ventilation.

$36,000 + 127,272 = 163,272$ B. T. U. = the total heat required, and this in turn divided by 600 (the efficiency of indirect radiators under these conditions) gives 272 square feet of surface required.

In the case of a dwelling-house the conditions are somewhat changed, for a room having a comparatively large exposure will perhaps have only 2 or 3 occupants, so that if the small air quantity necessary in this case was used to convey the required amount of heat to the room, it would have to be raised to an excessively high temperature. It has been found by experience that the radiating surface necessary for indirect heating is about 50 per cent greater than that required for direct heating. So for this work we may compute the surface required for direct radiation and multiply the result by 1.5.

Buildings like hospitals are in a class between dwellings and school houses. The air supply is based on the number of occupants, as in schools, but other conditions conform more nearly to dwelling houses.

To obtain the radiating surface for buildings of this class, we compute the total heat required for warming and ventilation as in the case of schoolhouses, and divide this sum by the efficiencies given for dwellings, that is 440 for zero weather and 460 for 10 degrees below.

Example. A hospital ward requires 50,000 cubic feet of air per hour for ventilation, and the heat loss by conduction through walls, etc. is 100,000 B. T. U. per hour. How many square feet of indirect radiation will be required to warm the ward in zero weather.

$(50,000 \times 70) \div 55 = 63,636$ B. T. U. for ventilation : then,

$$\frac{63,636 + 100,000}{440} = 372 + \text{square feet.}$$

Example.—A school room having 40 pupils is to be warmed and ventilated when it is 10 degrees below zero. If the heat loss by conduction is 30,000 B. T. U. per hour and the air supply is to be 40 cubic feet per minute per pupil, how many square feet of indirect radiation will be required?

B. T. U. required for ventilation per hour

$$= (40 \times 40 \times 60 \times 80) \div 55 = 139,636.$$

Total B. T. U. required = $139,636 + 30,000 = 169,636$.

Surface required = $169,636 \div 620 = 273$ square feet.

Example.—The heat loss from a sitting room is 11,250 B. T. U. per hour in zero weather. How many square feet of indirect radiation will be required to warm it?

From Part I, page 56, we have $11250 \div 225 = 50$ square feet; here, then, we need $50 \times 1.5 = 75$ square feet.

Warm-Air Flues. The required size of the warm-air flue between the heater and the register, depends first upon the difference in temperature between the air in the flue and that of the room, and second, upon the height of the flue. In dwellings, hospitals, etc., where the conditions are practically constant, it is customary to allow 2 square inches area for each square foot of radiation when the room is on the first floor, and $1\frac{1}{2}$ square inches when it is on the second floor.

In schoolhouse work it is more usual to calculate the size of flue from an assumed velocity of air flow through it. This will vary greatly according to the outside temperature and the prevailing

wind conditions. The following figures may be taken as average velocities obtained in practice, and may be used as a basis for calculating the required flue areas for the different stories of a school building.

1st floor	280	feet	per	minute.
2nd "	340	"	"	"
3rd "	400	"	"	"

These velocities will be increased somewhat in windy weather and will be reduced when the atmosphere is damp.

Having assumed these velocities, and knowing the number of cubic feet of air to be delivered to the room per minute, we have only to divide this quantity by the assumed velocity, to obtain the required flue area in square feet.

Example — A schoolroom on the second floor is to have an air supply of 2,000 cubic feet per minute; what will be the required flue area?

$$2000 \div 340 = 5.8 + \text{sq. feet Ans.}$$

The velocities would be higher in the coldest weather and dampers should be placed in the flues for throttling the air supply when necessary.

Cold-Air Ducts. The cold-air ducts supplying heaters should be planned in a similar manner to that described for furnace heating. The air inlet should be on the north or west side of the building, but this of course is not always possible. The method of having a large trunk line or duct with inlets on two or more sides of the building should be carried out when possible. A cold-air room with large inlet windows, and ducts connecting with the heaters make a good arrangement for schoolhouse work. The inlet windows in this case should be provided with check valves to prevent any outward flow of air. A detail of this arrangement is shown in Fig. 13.

This consists of a boxing around the window, extending from the floor to the ceiling. The front is sloped as shown and is closed from the ceiling to a point below the bottom of the window. The remainder is open and covered with a wire netting of about $\frac{1}{2}$ inch mesh; to this are fastened flaps or checks of gossamer cloth about 6 inches in width. These are hemmed on both edges and a stout wire is run through the upper hem which is fastened

to the netting by means of small copper or soft iron wire. The checks allow the air to flow inward but close when there is any tendency for the current to reverse.

The area of the cold-air duct for any heater should be about three-fourths the total area of the warm air ducts leading from it.

A common rule for dwelling houses and similar work is to allow $1\frac{1}{2}$ square inches of area for each square foot of radiating surface. The inlet windows should be provided with some form of damper or slide, outside of which should be placed a wire grating, backed by a netting of about $\frac{3}{8}$ inch mesh.

Vent Flues. In dwelling houses vent flues are often omitted and the frequent opening of doors and leakage are depended upon to carry away the impure air. A well designed system of warming should provide some means

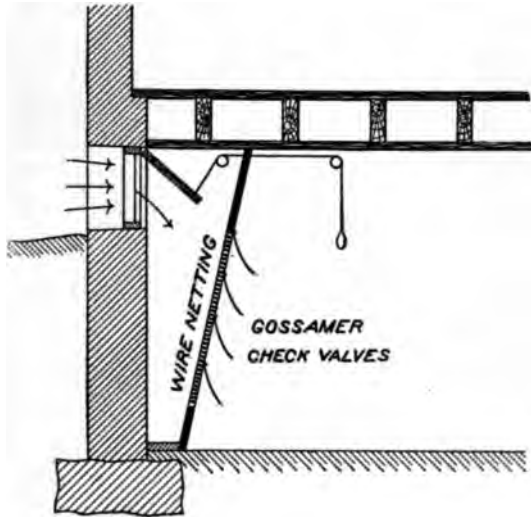


Fig. 13.

for discharge ventilation, especially for bath and toilet rooms, and also for living rooms where lights are burned in the evening. The sizes of flues may be made the reverse of the warm-air flues, that is, $1\frac{1}{2}$ square inches area per square foot of indirect radiation for rooms on the first floor and 2 square inches for those on the second. This is because the velocity of flow will depend upon the height of flue and will therefore be greater from the first floor. The flues should be joined together in the attic and then carried through the roof where a ventilating hood should be provided, especially designed to keep out the rain and snow. A good form is shown in Fig. 14.

Very good results may be obtained by simply letting the flues open into an unfinished attic and depending upon leakage through

the roof to carry away the foul air. The flow of air through the vents will be slow at best unless some means is provided for warming the air in the flue to a temperature above that of the room with which it connects. This may be done by carrying up a loop of steam pipe inside of the flue. It should be connected for drainage and air venting as shown in Fig. 15.

For schoolhouse work we may assume average velocities through the vent flues as follows :

1st floor	340	feet	per	min.
2nd "	280	"	"	"
3rd "	220	"	"	"

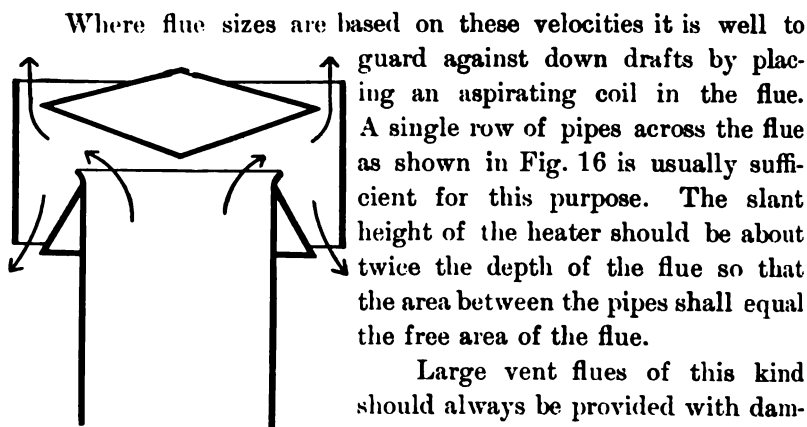


Fig. 14.

Large vent flues of this kind should always be provided with dampers for closing at night and for regulation during strong winds.

Sometimes it is desired to move a given quantity of air through a flue which is already in place.

Table I shows what velocities may be obtained through flues of different heights for varying differences in temperature between the outside air and that in the flue.

Example. — It is desired to discharge 1300 cubic feet of air per minute through a flue having an area of 4 square feet and a height of 30 feet. If the efficiency of an aspirating coil is 400 B. T. U. how many square feet of surface will be required to move this amount of air when the temperature of the room is 70° and the outside temperature is 60° ?

$1300 \div 4 = 325$ feet per minute = velocity through the flue. Looking in table I and following along the line oppo-

site a 30-foot flue we find that to obtain this velocity there must be a difference of 30 degrees between the air in the flue and the external air. If the outside temperature is 60 degrees then the air in the flue must be raised to $60 + 30 = 90$ degrees. The air

TABLE I.

Height of Flue in Feet.	Excess of Temperature of Air in Flue above that of External Air.					
	5°	10°	15°	20°	30°	50°
5	55	76	94	109	134	167
10	77	108	133	153	188	242
15	94	133	162	188	230	297
20	108	153	188	217	265	342
25	121	171	210	242	297	383
30	133	188	230	265	325	419
35	143	203	248	286	351	453
40	153	217	265	306	375	484
45	162	230	282	325	398	514
50	171	242	297	342	419	541
60	188	264	325	373	461	594

of the room being at 70 degrees, a rise of 20 degrees is necessary, so the problem resolves itself into the following — What amount of heating surface, having an efficiency of 400 B. T. U. is neces-

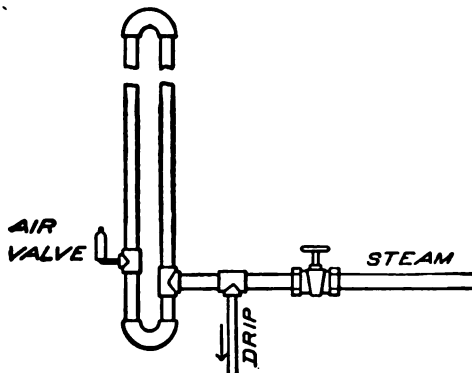


Fig. 15.

sary to raise 1300 cubic feet of air per minute through 20 degrees?
 1300 cubic feet per minute = $1300 \times 60 = 78,000$ per hour,

and making use of our formula for "heat for ventilation," we have

$$\frac{78,000 \times 20}{55} = 28,363 \text{ B. T. U.},$$

and this divided by 400 = 71 square feet of heating surface required.

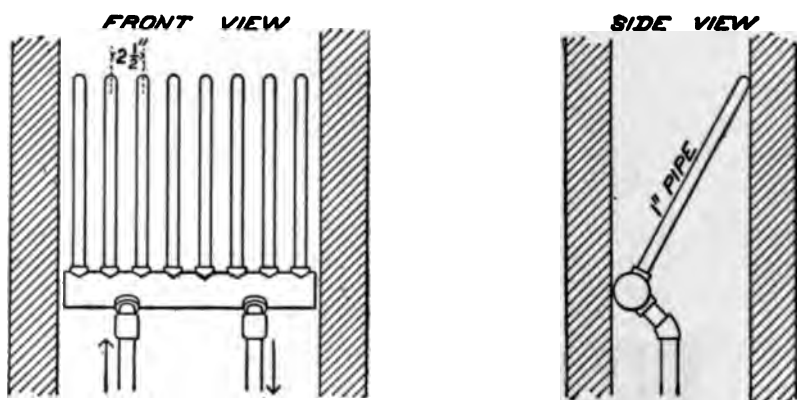


Fig. 16.

Example.—What size of heater will be required in a vent flue 40 feet high and with an area of 5 square feet, to enable it to discharge 1530 cubic feet per minute, when the outside temperature is 60°? (Assume a heater efficiency of 400 B. T. U.)

Velocity in flue = $1530 \div 5 = 306$ feet per minute.

Temperature excess, from Table I, = 20 degrees.

B. T. U. required per hour = $1530 \times 60 \times 10 \div 55 = 16690$ requiring $16690 \div 400 = 41.7$ square feet of heater.

Registers. Registers are made of cast iron and bronze, in a great variety of sizes and patterns. The universal finish for cast iron is black "Japan"; they are also finished in colors and electroplated with copper and nickel. Fig. 17 shows a section through a floor register in which "A" represents the valves, which may be turned in a vertical or horizontal position, thus opening or closing the register; "B" is the iron border, "C" the register box of tin or galvanized iron and "D" the warm-air pipe. Floor registers

are usually set in cast iron borders, one of which is shown in Fig. 18, while wall registers may be screwed directly to wooden borders or frames to correspond with the finish of the room. Wall registers should be provided with pull cords for opening and closing from the floor; these are shown in Fig. 19. The plain lattice pattern shown in Fig. 20 is the best for schoolhouse work as it has a comparatively free opening for air flow and is pleasing and simple in design. More elaborate patterns are used for fine dwelling-house work. Registers with shut-off valves are used for air inlets while the plain register faces without the valves are placed in the vent openings. The vent flues are usually

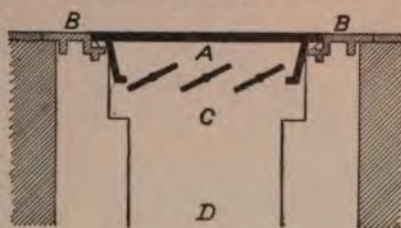


Fig. 17.



Fig. 18.

gathered together in the attic and a single damper may be used to shut off the whole number at once. Flat or round wire gratings of open pattern are often used in place of register faces. The grill or solid part of a register face usually takes up about $\frac{1}{3}$ of the area, hence in computing the size we must allow for this by multiplying the required "net area" by 1.5 to obtain the "total" or "over all" area.

For example, suppose we have a flue 10 inches in width and

wish to use a register having a free area of 200 square inches, what will be the required height of the register? $200 \times 1.5 = 300$ square inches which is the total area required, then $300 \div 10 = 30$, which is the required height and we should use a $10'' \times 30''$ register. When a register is spoken of as a $10'' \times 30''$ or $10'' \times 20''$, etc. the dimensions of the latticed opening is meant, and not the outside dimensions of the whole register. The free opening should have the same area as the flue with which it



Fig. 19.



Fig. 20.

connects. In designing new work one should provide himself with a trade catalogue, and use only standard sizes as special patterns and sizes are costly. Fig. 21 shows the method of placing gossamer check valves back of the vent register faces to prevent down drafts, the same as described for fresh-air inlets.

Pipe Connections. The two-pipe system with dry or sealed returns is used in indirect heating. The conditions to be met are practically the same as in direct heating, the only difference being that the radiators are at the basement ceiling instead of on the floors above. The exact method of making the pipe connections will depend somewhat upon existing conditions, but the

general method shown in Fig. 22 may be used as a guide with modifications to suit any special case. The ends of all supply mains should be dripped, and the horizontal returns should be sealed if possible.

Pipe Sizes. The tables already given for the proportioning of pipe sizes can be used for indirect systems. The following table has been computed for an efficiency of 640 B. T. U. per square foot of surface per hour, which corresponds to a condensa-

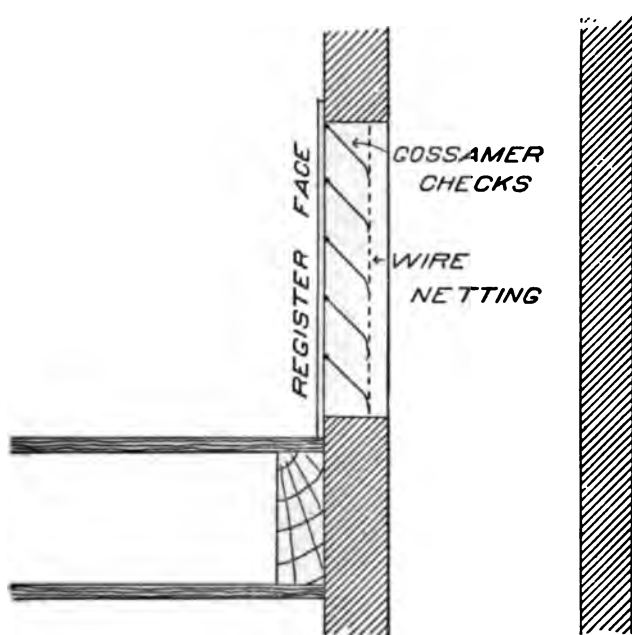


Fig. 21.

tion of $\frac{2}{3}$ of a pound of steam. This is twice that allowed for direct radiation in table XIII. of Part I., so that we can consider 1 square foot of indirect surface as equal to 2 of direct in computing pipe sizes.

As the indirect heaters are placed in the basement, care must be taken that the bottom of the radiator does not come too near the water line of the boiler, or the condensation will not flow back properly; this distance should not be less than 2 feet under ordinary conditions. If much less than this, the pipes should be made extra large so there may be little or no drop in pressure

between the boiler and the heater. A drop in pressure of 1 pound would raise the water line at the heater 2.4 feet.

Direct-Indirect Heating. The general form of a direct-indirect radiator has been shown in Figs. 10 and 11 of Part I. Another form where the air is admitted to the radiator through the wall instead of the floor is shown in Fig. 23. Fig. 24 shows the wall

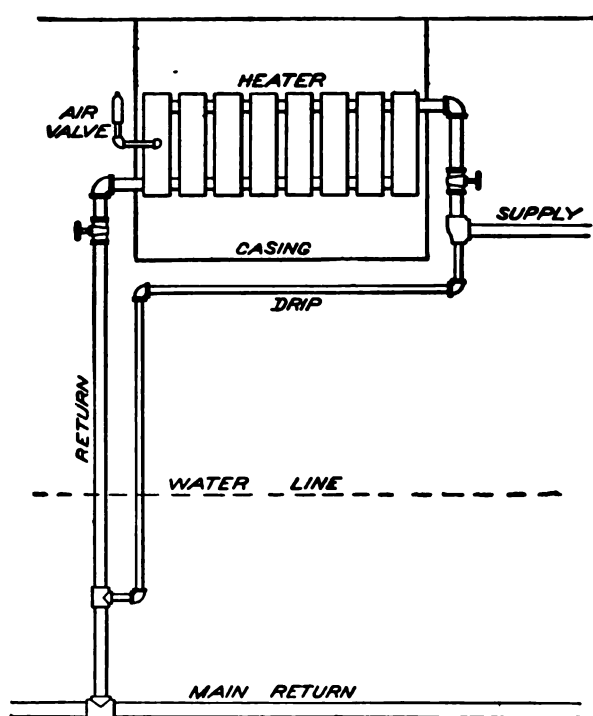


Fig. 22.

box with louvre slats, and netting, through which the air is drawn. A damper door is placed at either end of the radiator base, and if desired, when the cold air supply is shut off by means of the register in the air duct, the radiator can be converted into the ordinary type by opening both damper doors, thus taking the air from the room instead of from the outside. It is customary to increase the size of a direct-indirect radiator 30 per cent. above that called for in the case of direct heating.

TABLE II.

Size of Pipe.	Square Feet of Indirect Radiation which will be Supplied with		
	$\frac{1}{2}$ Pound Drop in 200 Feet.	$\frac{1}{2}$ Pound Drop in 100 Feet.	$\frac{1}{2}$ Pound Drop in 100 Feet.
1	28	40	57
1 $\frac{1}{4}$	51	72	105
1 $\frac{1}{2}$	67	95	170
2	185	262	375
2 $\frac{1}{2}$	335	475	675
3	540	775	1105
3 $\frac{1}{2}$	812	1160	1645
4	1140	1625	2310
5	2030	2900	4110
6	3260	4660	6600
7	4830	6900	9810
8	6800	9720	13860

CARE AND MANAGEMENT OF STEAM HEATING BOILERS.

Special directions are usually supplied by the maker for each kind of boiler, or for those which are to be managed in any peculiar way. The following general directions apply to all makes, and may be used regardless of the type of boiler employed.

Before starting the fire see that the boiler contains sufficient water. The water line should be at about the center of the gage glass.

The smoke pipe and chimney flue should be clean and the draft good.

Build the fire in the usual way, using a quality of coal which is best adapted to the heater. In operating the fire keep the fire-pot full of coal and shake down and remove all ashes and cinders as often as the state of the fire requires it.

Hot ashes or cinders must not be allowed to remain in the ash pit under the grate bars but must be removed at regular intervals to prevent burning out the grate.

To control the fire see that the damper regulator is properly attached to the draft doors, and the damper; then regulate the draft by weighting the automatic lever as may be required to

obtain the necessary steam pressure for warming. Should the water in the boiler escape by means of a broken gage glass, or from any other cause, the fire should be dumped, and the boiler allowed to cool before adding cold water.

An empty boiler should never be filled when hot. If the water gets low at any time, but still shows in the gage glass,

more water should be added by the means provided for this purpose.

The safety valve should be lifted occasionally to see that it is in working order.

If the boiler is used in connection with a gravity system it should be cleaned each year by filling with pure water and emptying through the blow-off. If it should become foul or dirty it can be thoroughly cleansed by adding a few pounds of caustic soda and allowing it to stand for a day and then emptying and thoroughly rinsing.

During the summer months it is recommended that the

water be drawn off from the system, and that air valves and safety valves be opened to permit the heater to dry out and to remain so.

Good results are however obtained by filling the heater full of water, driving off the air by boiling slowly, and allowing it to remain in this condition until needed in the fall. The water should then be drawn off and fresh water added.

The heating surface of the boiler should be kept clean and free from ashes and soot by means of a brush made especially for this purpose.

Should any of the rooms fail to heat, examine the steam valves at the radiators. If a two-pipe system both valves at



Fig. 23.

each radiator must be opened or closed at the same time as required. See that the air valves are in working condition.

If the building is to be unoccupied in cold weather draw all the water out of the system by opening the blow-off pipe at the boiler and all steam and air valves at the radiators.

HOT WATER HEATERS.

Types. Hot water heaters differ from steam boilers principally in the omission of the reservoir or space for steam above the heating surface. The steam boiler might answer as a heater for hot water, but the large capacity left for the steam would tend to make its operation slow and rather unsatisfactory, although the



Fig. 24.

same type of boiler is sometimes used for both steam and hot water. The passages in a hot water heater need not extend so directly from bottom to top as in a steam boiler, since the problem of providing for the free liberation of the steam bubbles does not have to be considered. In general, the heat from the furnace should strike the surfaces in such a manner as to increase the natural circulation; this may be accomplished to a certain extent by arranging the heating surface so that a large proportion of the direct heat will be absorbed near the top of the heater. Practically the boilers for low-pressure steam and for hot water differ from each other very little as to the character of the heating-surface, so that the methods already given for computing the size of grate surface, horsepower, etc., under the head of steam boilers can be used with satisfactory results in the case of hot water heaters. It is sometimes stated that owing to the greater difference in temperature between the furnace gases and the water in a hot water heater, as compared with steam, that the heating surface will be more efficient and that a smaller heater can be used.

while this is true to a certain extent different authorities agree that this advantage is so small that no account should be taken of it, and the general proportions of the heater should be calculated in the same manner as for steam. Fig. 25 shows a form of hot-water heater made up of slabs or sections similar to the sectional steam boiler shown in Part I; the size can be increased in the same way by adding more slabs. A different form is shown in Fig. 26. This is made of cast iron but is not a sectional boiler.

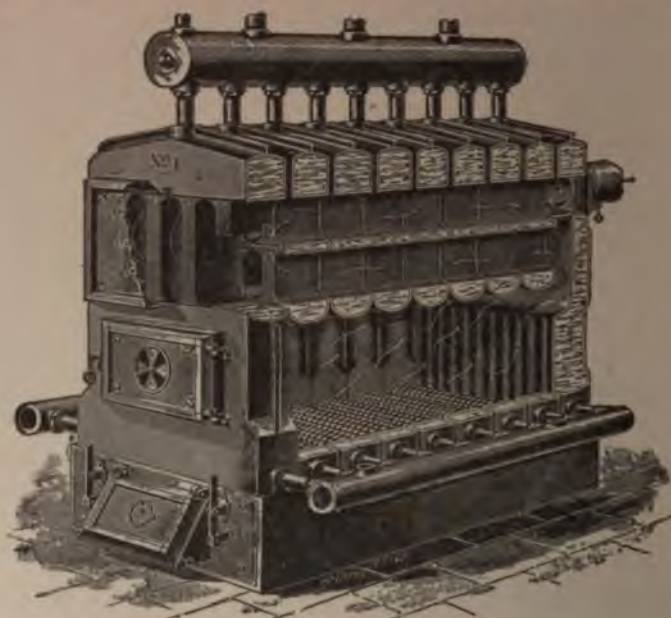


Fig. 25.

It has no horizontal flues for the ashes and soot to collect in and a greater part of the heating surface is directly exposed to the hottest part of the fire. Fig. 27 shows another form of heater similar in principle to the one just described. The space between the outer and inner shells surrounding the furnace is filled with water and also the cross pipes directly over the fire and the drum at the top. The supply to the radiators is taken off from the top of the heater and the return connects at the lowest point.

The ordinary horizontal and vertical tubular boilers with various modifications are used to quite an extent for hot water

heating and are well adapted to this class of work, especially in the case of large buildings.

Automatic regulators are often used for the purpose of main-

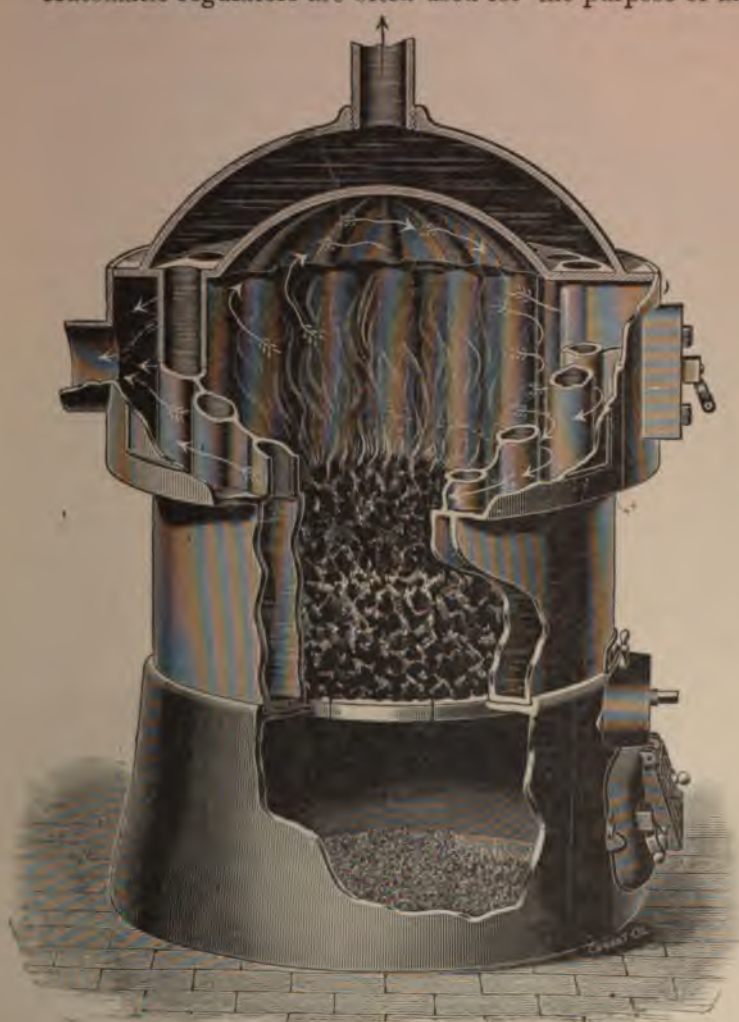


Fig. 26.

taining a constant temperature of the water. They are constructed in different ways — some depend upon the expansion of a metal pipe or rod at different temperatures, and others upon the vapor-

ization and consequent pressure of certain volatile liquids. These means are usually employed to open small valves which admit water pressure under rubber diaphragms, and these in turn are connected by means of chains with the draft doors of the furnace, and so regulate the draft as required to maintain an even temperature of the water in the heater. Fig. 28 shows one of the first kind. "A" is a metal rod placed in the flow pipe from the heater, and is so connected with the valve "B" that when the water



Fig. 27.

reaches a certain temperature the expansion of the rod opens the valve and admits water from the street pressure through the pipes "C" and "D" into the chamber "E." The bottom of "E" consists of a rubber diaphragm which is forced down by the water pressure and carries with it the lever which operates the dampers as shown, and checks the fire. When the temperature of the water drops, the rod contracts and valve "B" closes, shutting off the

pressure from the chamber "E." A spring is provided to throw the lever back to its original position and the water above the diaphragm is forced out through the pet cock "G" which is kept slightly open all of the time.

DIRECT HOT WATER HEATING.

A hot water system is similar in construction and operation to one designed for steam, except the *hot water* flows through the pipes, giving up its heat by conduction to the coils and radiators, which in turn transfer it to the air of the room by conduction and radiation.

The flow through the system is produced solely by the difference in weight of the water in the supply and return pipes, due to the difference in temperature. When water is heated it expands, and thus a given volume becomes lighter and tends to rise, and the cooler water flows in to take its place; if the application of heat is kept up the circulation thus produced is continuous. The velocity of flow depends upon the difference in temperature between the supply and return, and the height of radiator above the boiler. The horizontal distance of

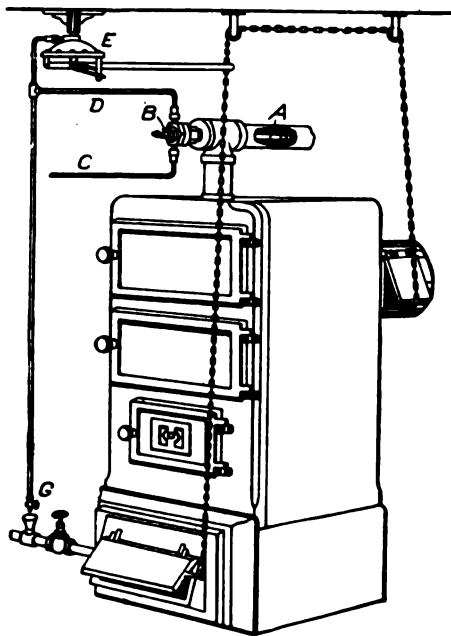


Fig. 28.

the radiator from the boiler is also an important factor.

Types of Radiating Surface. Cast iron radiators and circulation coils are used for hot water as well as for steam. Hot water radiators differ from steam radiators principally in having a horizontal passage at the top as well as at the bottom. This construction is necessary in order to draw off the air which

gathers at the top of each loop or section. Otherwise they are the same as steam radiators, and are well adapted for the circulation of steam, and in some respects are superior to the ordinary pattern.

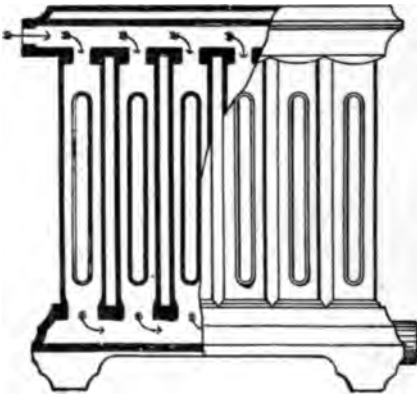


Fig. 29.

The form shown in Fig. 29 is made with an opening at the top for the entrance of water and at the bottom for its discharge, thus insuring a supply of hot water at the top and of colder water at the bottom.

Some hot water radiators are made with a cross-partition so arranged that all water entering passes at once to the top, from which it may take any passage toward the outlet. Fig. 30 is the more common form of radiator, and is made with continuous

passages at top and bottom; the hot water is supplied at one side and drawn off at the other. The action of gravity is depended upon for making the hot and lighter water pass to the

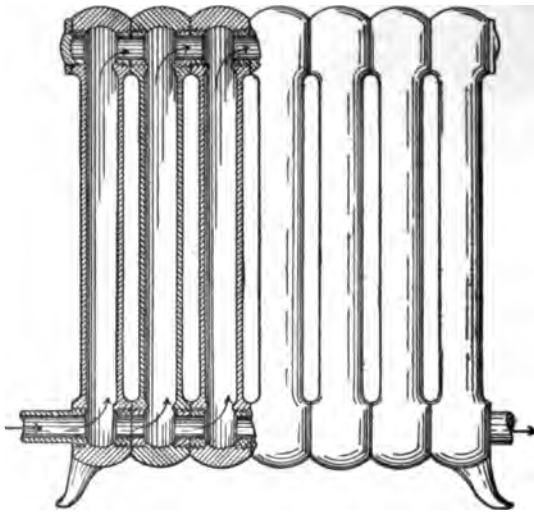


Fig. 30.

passages at top and bottom; the hot water is supplied at one side and drawn off at the other. The action of gravity is depended upon for making the hot and lighter water pass to the

top, and the colder water sink to the bottom and flow off through the return. Hot water radiators are usually tapped and plugged so that the pipe connections can be made either at the top or at the bottom. This is shown in Fig. 31.

Efficiency of Radiators. The efficiency of a hot water radiator depends entirely upon the temperature at which the water is circulated. The best practical results are obtained with the water leaving the boiler at a maximum temperature of about 180 degrees in zero weather and returning at about 160 degrees; this gives an average temperature of 170 in the radiators. Variations may be made however to suit the existing conditions of outside temperature. We have seen that an average cast iron radiator gives off about 1.5 B. T. U. per hour per square foot of surface per degree difference in temperature between the surrounding air and the radiator, when working under ordinary conditions, and this holds true whether filled with steam or water.

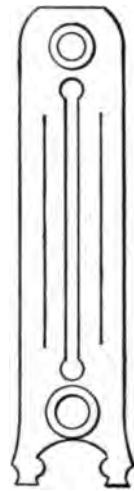


Fig. 31.

If we assume an average temperature of 170 degrees for the radiators then the difference will be $170 - 70 = 100$ degrees, and this multiplied by $1.5 = 150$ which may be taken as the efficiency of a hot water radiator under the above conditions, which represent good average practice.

This calls for a water radiator about 1.5 times as large as a steam radiator to heat a given room under the same conditions. This is common practice although some engineers multiply by the factor 1.6 which allows for a lower temperature of the water. Water leaving the boiler at 170 degrees should return at about 150; the drop in temperature should not ordinarily exceed 20 degrees.

System of Piping. A system of hot water heating should produce a perfect circulation of water from the heater to the radiating surface, and thence back to the heater through the returns. The system of piping usually employed for hot water heating is shown in Fig. 32. In this arrangement the main and branches have an inclination upward from the heater; the returns are

parallel to the mains and have an inclination downward toward the heater, and connect with it at the lowest point. The flow pipes or risers are taken from the tops of the mains and may supply one or more radiators as required. The return risers or drops are connected with the return mains in a similar manner. In this system great care must be taken to produce a nearly equal resistance to flow in all of the branches so that each radiator may receive its full supply of water. It will always be found that the principal current of heated water will take the path of least resistance, and that a small obstruction or irregularity in the piping is

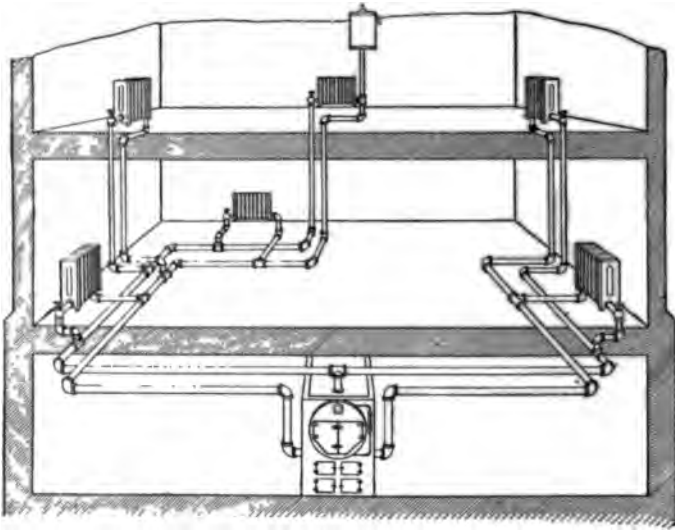


Fig. 32.

sufficient to interfere greatly with the amount of heat received in the different parts of the same system.

Expansion Tank. Every system for hot water heating should be connected with an expansion tank placed at a point somewhat above the highest radiator. The tank must in every case be connected to a line of piping which cannot by any possible means be shut off from the boiler. When water is heated, it expands a certain amount, depending upon the temperature to which it is raised and a tank or reservoir should always be provided to care for this increase in volume.

Expansion tanks are usually made of heavy galvanized iron



ROCOCO ORNAMENTAL THREE COLUMN PATTERN RADIATOR FOR
WARMING BY HOT WATER.
American Radiator Company.



of one of the forms shown in Figs. 33 and 34, the latter being used where the head room is limited. The connection from the heating system enters the bottom of the tank and an open vent pipe is taken from the top. An overflow connected with a sink or drain pipe should be provided. Connections should be made with the water supply both at the boiler and at the expansion tank, the former to be used when first filling the system, as by this means all air is driven from the bottom upward and is discharged through the vent at the expansion tank. Water that is added afterward may be supplied directly to the expansion tank where the water line can be noted in the gage glass. A ball cock is often arranged to keep the water line in the tank at a constant level.

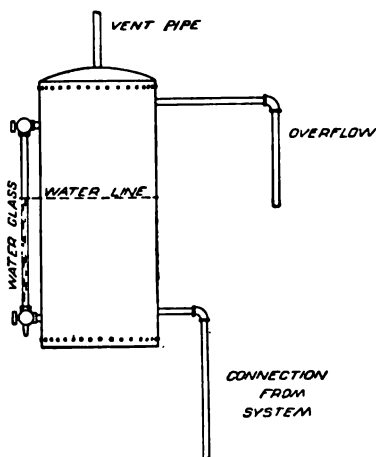


Fig. 33.

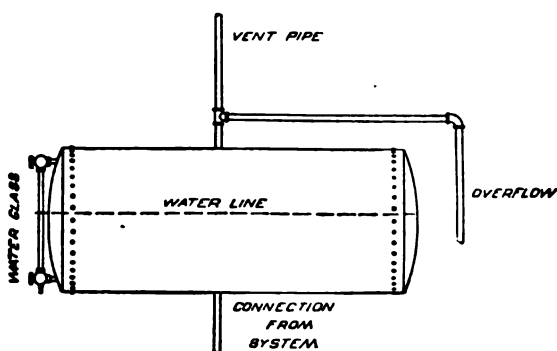


Fig. 34.

The size of the expansion tank depends upon the volume of water contained in the system, and the temperature to which it is heated. The following rule for computing the capacity of the tank may be used with satisfactory results.

The square feet of radiation divided by 40 equals the required capacity of the tank in gallons.

Overhead Distribution. This system of piping is shown in Fig. 35. A single riser is carried directly to the expansion tank, from which branches are taken to supply the various drops to which the radiators are connected. An important advantage in connection with this system is that the air rises at once to the expansion tank and escapes through the vent, so that air valves are not required on the radiators.

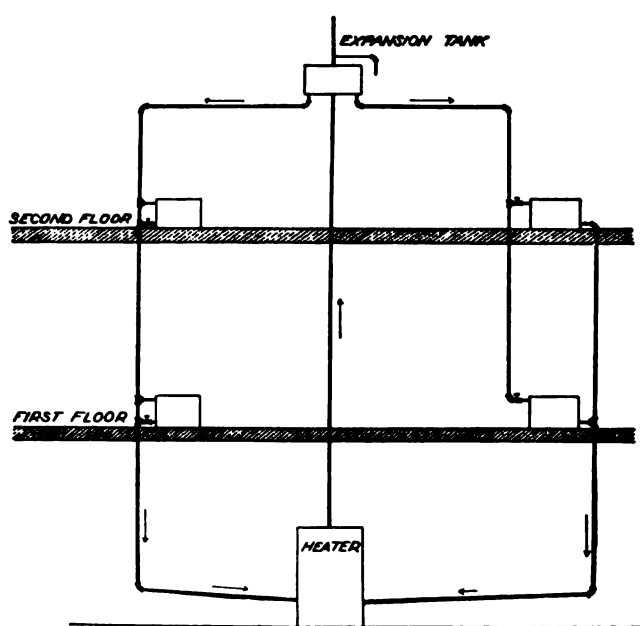


Fig. 35.

Pipe Connections. There are various methods of connecting the radiators with the mains and risers. Fig. 36 shows a radiator connected with the horizontal flow and return mains which are located below the floor. The manner of connecting with a vertical riser and return drop is shown in Fig. 37. As the water tends to flow to the highest point, the radiators on the lower floors should be favored by making the connection at the top of the riser and taking the pipe for the upper floors from the side as shown. Fig. 38 illustrates the manner of connecting with a radiator on an upper floor where the supply is connected at the top of the radiator.

The connections shown in Figs. 39 and 40 are used with the overhead system shown in Fig. 35.

Where the connection is of the form shown at the left in Fig. 35, the cooler water from the radiators is discharged into the supply pipe again so that the water furnished to the radiators on

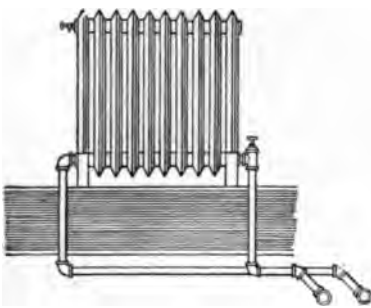


Fig. 36.

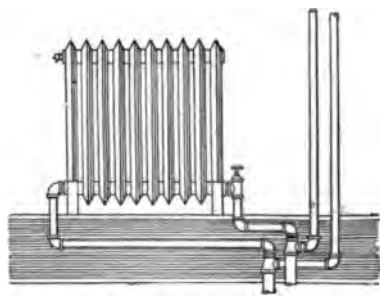


Fig. 37.

the lower floors is at a lower temperature, and the amount of heating surface must be correspondingly increased to make up for this loss.

For example.—If in the case of Fig. 35 we assume the water to leave the heater at 180 degrees and return at 160 we

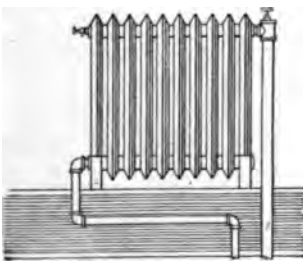


Fig. 38.

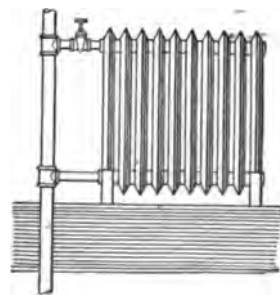


Fig. 39.

shall have a drop in temperature of 10 degrees on each floor, that is, the water will enter the radiator on the second floor at 180 degrees and leave it at 170 and will enter the radiator on the first floor at 170 and leave it at 160. The average temperatures will be 175 and 165 respectively. The efficiency in the first

case will be $175 - 70 = 105$ and $105 \times 1.5 = 157$. In the second case $165 - 70 = 95$ and $95 \times 1.5 = 142$, so that the radiator on the first floor will have to be larger than that on the second floor in the ratio of 157 to 142, in order to do the same work.

Where the radiators discharge into a separate return as in the case of Fig. 32 or those at the right in Fig. 35, we may assume the temperature of the water to be the same on all floors and give the radiators an equal efficiency.

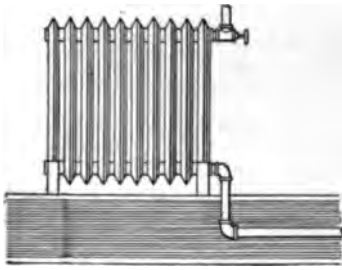


Fig. 40.

In a dwelling house of two stories no difference would be made in the sizes of radiators on the two floors, but in the case of a tall office building corrections would necessarily be made as described.

Where circulation coils are used they should be of a form which will tend to produce a flow of water through them. Figs. 41, 42 and 43 show different ways of making up and connecting these coils. In Figs. 41 and 43 the supply pipes may be either drops or risers, and in the latter

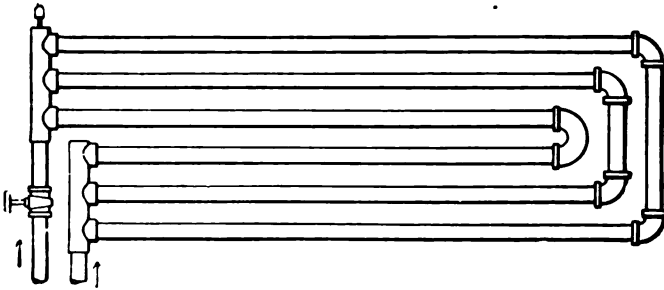


Fig. 41.

case the return in Fig. 43 may be carried back if desired into the supply drop as shown by the dotted lines.

Combination Systems. Sometimes the boiler and piping are arranged for either steam or hot water, since the demand for a higher or lower temperature of the radiators might change.

The object of this arrangement is to secure the advantages

of a hot water system for moderate temperatures, and of steam heating for extremely cold weather.

As less radiating surface is required for steam heating, there is an advantage due to the reduction in first cost. This is of con-

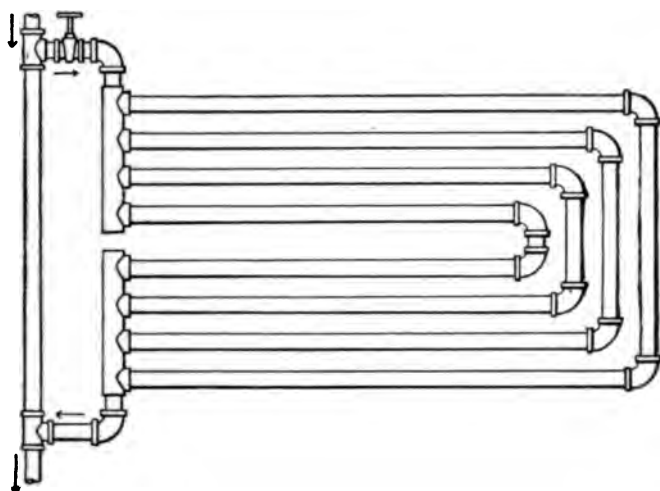


Fig. 42.

siderable importance, as a heating system must be designed of such dimensions as to be capable of warming a building in the

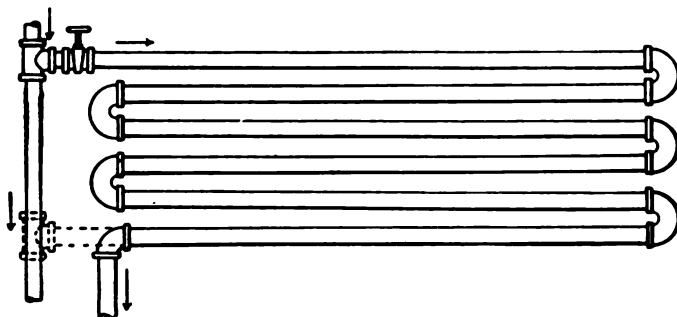


Fig. 43.

coldest weather, and this involves the expenditure of a considerable amount for radiating surfaces, which are needed only at rare intervals. A combination system of hot water and steam heating requires, first, a heater or boiler which will answer for either pur-

pose; second, a system of piping which will permit the circulation of either steam or hot water; and third, the use of radiators which are adapted to both kinds of heating. These requirements will be met by using a steam boiler provided with all the fittings required for steam heating, but so arranged that the damper regulator may

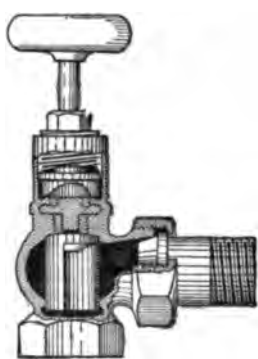


Fig. 44.

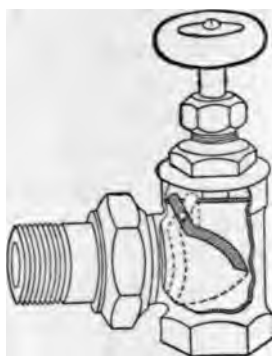


Fig. 45.

be closed by means of valves when the system is to be used for hot water heating. The addition of an expansion tank is required, which must be so arranged that it can be shut off when the system is used for steam heating. The system of piping

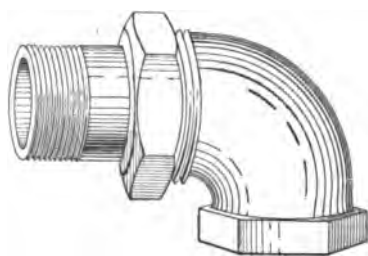


Fig. 46.

shown in Fig. 32 is best adapted for a combination system, although an overhead distribution as shown in Fig. 35 may be used, by shutting off the vent and overflow pipes, and placing air valves on the radiators.

While this system has many advantages in the way of cost over the complete hot water system, yet the labor of changing from steam to hot water will in some cases be troublesome, and should the connections to the expansion tank not be opened, serious results would follow.

Valves and Fittings. Gate valves should always be used in connection with hot water piping, although angle valves may

be used at the radiators. There are several patterns of radiator valves made especially for hot water work ; their chief advantage lies in a device for quick closing, usually a quarter or half turn being sufficient to open or close the valve. Two different designs are shown in Figs. 44 and 45.

It is customary to place a valve in only one connection as that is sufficient to stop the flow of water through the radiator; a fitting known as a "union elbow" is often employed in place of the second valve. (See Fig. 46.)

Air Valves. The ordinary pet-cock air valve is the most reliable for hot-water radiators, although there are several forms of automatic valves which are claimed to give satisfaction. One of these is shown in Fig. 47. This is similar in construction to a steam trap. As air collects in the chamber, and the water line is lowered, the float drops, and in so doing opens a small valve at the top of the chamber which allows the air to escape. As the water flows in to take its place the float is forced upward and the valve is closed.

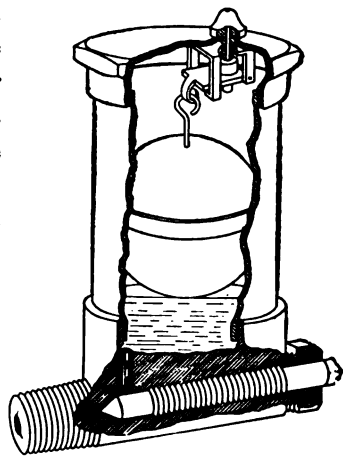


Fig. 47.

All radiators which are supplied by risers from below should be provided with air valves placed in the top of the last section at the return end. If they are supplied by drops from an overhead system the air will be discharged at the expansion tank and air valves will not be necessary at the radiators.

Fittings. All fittings, such as elbows, tees, etc., should be of the "long turn" pattern. If the common form is used, they should be a size larger than the pipe, bushed down to the proper size. The long turn fittings, however, are preferable.

Pipe Sizes. The size of pipe required to supply any given radiator depends upon four conditions ; *first* the size of the radiator, *second* its elevation above the boiler, *third* the length of pipe required to connect it with the boiler, and *fourth* the difference in

temperature between the supply and return. The following illustration will serve to make these points clear.

If we should take a glass tube of the form shown in Fig. 48, fill it with water and hold it in a vertical position, we would notice that the water remained perfectly quiet; now if the flame of a lamp were held near the tube A and a few drops of coloring matter were poured into the tube, we would find that the water was in motion, and the current would be in the direction shown by the arrows. While the water in both tubes was at the same temperature, the two columns were of the same weight and remained in equilibrium. If, however, the water in column A is heated, it expands and becomes

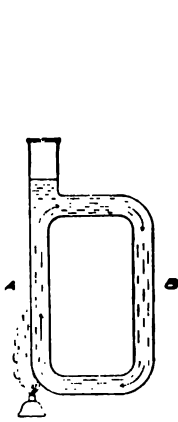


Fig. 48.

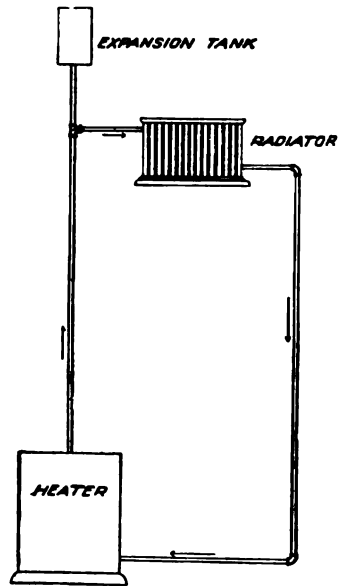


Fig. 49.

lighter than column B, and is forced upward by the heavier water falling toward the bottom of the tube. The heated water flows across the top and into B where it takes the place of the cooler water which is settling to the bottom. As long as there is a difference in the temperature of the two columns this action will continue. If now we replace the lamp by a furnace, and connect the two columns A and B at the top by inserting a radiator, we

shall have the same illustration in practical form as utilized in hot water heating. (See Fig. 49).

The heat given off by the radiator always insures a difference in temperature between the columns of water in the supply and return pipes, so that as long as heat is supplied by the furnace the flow of water will continue. The greater the difference in temperature of the water in the two pipes, the greater the difference in weight, and consequently the faster the flow. The greater the height of the radiator above the heater the more rapid the flow, for the difference in weight between two columns 1 foot high and two columns 10 feet high is ten times as great and if there were no friction in the pipes the flow would be directly proportional to the elevation of the radiator above the heater. The quantity of water discharged by a given pipe under constant pressure varies inversely as the length of pipe; that is, if a pipe 100 feet long will discharge 10 gallons per minute under a given pressure, it will discharge only half as many gallons if the length is increased to 200 feet, the pressure remaining the same.

As it would be a long process to work out the required size of each pipe for a heating system, the following tables have been prepared, covering the usual conditions to be met with in practice.

Table III gives the number of square feet of direct radiation which different sizes of mains will supply for varying lengths of run.

TABLE III.

Size of Pipe.	Square Feet of Radiating Surface.								
	100 ft. Run.	200 ft. Run.	300 ft. Run.	400 ft. Run.	500 ft. Run.	600 ft. Run.	700 ft. Run.	800 ft. Run.	1000 ft. Run.
1	30								
1¼	60	50							
1½	100	75	50						
2	200	150	125	100	75				
2½	350	250	200	175	150	125			
3	550	400	300	275	250	225	200	175	150
3½	850	600	450	400	350	325	300	250	225
4	1200	850	700	600	525	475	450	400	350
5		1400	1150	1000	700	850	775	725	650
6				1600	1400	1300	1200	1150	1000
7							1700	1600	1500

These quantities have been calculated on a basis of 10 feet difference in elevation between the center of the heater and the radiators, and a difference in temperature of 17 degrees between the supply and return.

This table may be used for all horizontal mains. For the vertical risers or drops, table IV may be used. This has been computed for the same difference in temperature, and gives the square feet of surface which different sizes of pipe will supply on the different floors of a building, assuming the height of the stories to be 10 feet. Where a single riser is carried to the top of a building to supply the radiators on the floors below, by drop pipes, we must first get what is called the "average elevation of the system" before taking its size from the table. This may be illustrated by the following diagram, (see Fig. 50).

In A we have a riser carried to the third story and from there a drop brought down to supply a radiator on the first floor. The elevation available for producing a flow in the riser is only 10 feet, the same as though it extended only to the radiator. The water in the two pipes above the radiator is practically at the same temperature and therefore in equilibrium, and has no effect on the flow of the water in the riser. (Actually there would be some radiation from the pipes, and the return, above the radiator, would be slightly cooler, but for purposes of illustration this may be neglected). If the radiator was on the second floor the elevation of the system would be 20 feet (see B), and on the third floor 30 feet, and so on. The distance which the pipe is carried above the first radiator which it supplies has but little effect in producing a flow, especially if covered, as it should be in practice. Having seen that the flow in the main riser depends upon the elevation of the radiators, it is easy to see that the way in which it is distributed on the different floors must be considered. For example, in B, Fig. 50, there will be a more rapid flow through the riser with the radiators as shown than there would be if they were reversed and the larger one were placed upon the first floor.

We get the average elevation of the system by multiplying the square feet of radiation on each floor by the elevation above the heater, then adding these products together and dividing the same

by the total radiation in the whole system. In the case shown in B the average elevation of the system would be

$$\frac{(100 \times 30) + (50 \times 20) + (10 \times 25)}{100 + 50 + 25} = 24.3 \text{ feet,}$$

and we must proportion the main riser the same as though the

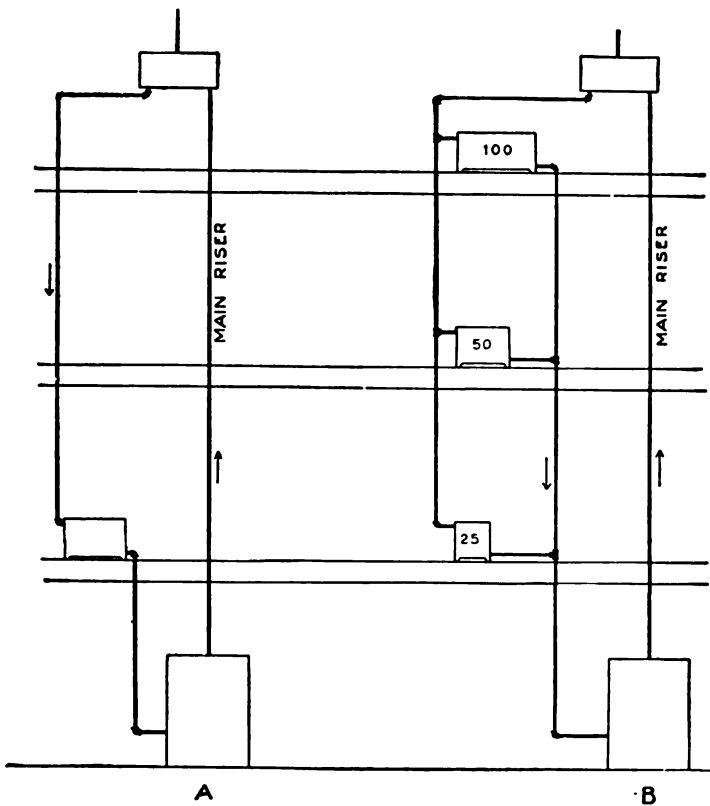


Fig. 50.

whole radiation were on the second floor. Looking in table IV we find for the second story that a $1\frac{1}{2}$ inch pipe will supply 140 square feet and a 2 inch pipe 275. Probably a $1\frac{1}{2}$ inch pipe would be sufficient

Although the height of the stories varies in different buildings,

10 feet will be found sufficiently accurate for ordinary practice.

TABLE IV.

Size of Riser.	Square Feet of Radiating Surface.					
	1st Story	2d Story	3d Story	4th Story	5th Story	6th Story
1	30	55	65	75	85	95
1½	60	90	110	125	140	160
1¾	100	140	165	185	210	240
2	200	275	375	425	500	
2½	350	475				
3	550					
3½	850					

INDIRECT HOT WATER HEATING.

Types of Heaters. The heaters for indirect hot water heating are of the same general form as those used for steam. The heaters shown in Figs. 9, 14 and 15 of Part I, are common patterns. The "drum pin," Fig. 14, is an excellent form, as the

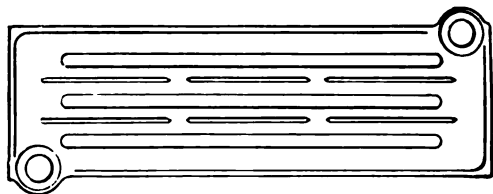


Fig. 51.

method of making the connections insures a uniform distribution of water through the stack.

Fig. 51 shows a section of good form for water circulation, and

also of good depth, which is a necessary point in the design of hot water heaters. They should not be less than 10 or 12 inches for good results. Box coils of the form given for steam may also be used, provided the connections for supply and return are made of good size.

Size of Heaters. As indirect hot water heaters are used principally in the warming of dwelling houses, and in combination with direct radiation, the easiest method is to compute the surfaces required for direct radiation and multiply these results by 1.5 for pin radiators of good depth. For other forms the factor should

vary from 1.5 to 2, depending upon the depth and proportion of free area for air flow between the sections.

If it is desired to calculate the required surface directly by the thermal unit method, we may allow an efficiency of from 360 to 380 for good types in zero weather.

Flues and Casings. For cleanliness, as well as for obtaining the best results, indirect stacks should be hung at one side of the register or flue receiving the warm air, and the cold-air duct should enter beneath the heater at the other side. A space of 10 inches, and preferably 12, should be allowed for the warm air above the stack. The top of the casing should pitch upward toward the warm-air outlet at least an inch in its length. A space of from 6 to 8 inches should be allowed for cold air below the stack.

As the amount of air warmed per square foot of heating surface is less than in the case of steam, we may make the flues somewhat smaller as compared with the size of heater. The following proportions may be used under usual conditions: $1\frac{1}{2}$ square inches per square foot of radiation for the first floor, and $1\frac{1}{4}$ square inches for the second floor, and $1\frac{1}{4}$ square inches for the cold-air duct.

Pipe Connections. In hot water indirect work it is not desirable to supply more than 80 to 100 square feet of radiation from a single connection. When the requirements call for larger stacks they should be divided into two or more groups according to the size.

The branches supplying the stacks should pitch upward from the boiler to a point directly over the stack, then drop and make connection with the heater at such a point as the special form in use requires. An air valve should be placed in the highest point of the pipe just before it drops to the heater. The return should be taken from the bottom of the stack and carried at a lower level back to the boiler or heater.

Conditions may make it necessary to bring back several separate returns to the heater, but it is better practice to use one large flow main and a single return of the same size, branching to the different stacks as necessary.

Pipe Sizes. As the difference in elevation between the

stacks and the heater is necessarily small, the pipes should be of ample size to offset the slow velocity of flow through them. The following sizes for runs up to 100 feet will be found ample for ordinary conditions. Some engineers make a practice of using somewhat smaller pipes, but the larger sizes will in general be found more satisfactory.

TABLE V.

Size of Pipe.	Square feet of Indirect Radiation.
1	15
1 $\frac{1}{4}$	30
1 $\frac{1}{2}$	50
2	100
2 $\frac{1}{2}$	200
3	300
3 $\frac{1}{2}$	400
4	600
5	1000

CARE AND MANAGEMENT OF HOT WATER HEATERS.

The directions given for the care of steam heating boilers apply in a general way to hot water heaters as to the methods of caring for the fires and for cleaning and filling the heater. Only the special points of difference need be considered. Before building the fire all the pipes and radiators must be full of water and the expansion tank should be partially filled as indicated by the gage glass. Should the water in any of the radiators fail to circulate, see that the valves are wide open and that the radiator is free from air. Water must always be added at the expansion tank when for any reason it is drawn from the system.

The required temperature of the water will depend upon the outside conditions and only enough fire should be carried to keep the rooms comfortably warm. Thermometers should be placed in the flow and return pipes near the heater as a guide. Special forms are made for this purpose in which the bulb is immersed in a bath of oil or mercury. See Fig. 52.

EXHAUST STEAM HEATING.

Steam after being used in an engine contains the greater part of its heat, and if not condensed or used for other purposes it can

usually be employed for heating without affecting to any great extent the power of the engine.

The systems of steam heating which have been described are those in which the water of condensation flows back into the boiler by gravity; where exhaust steam is used the pressure is much below that of the boiler and it must be returned either by a pump or return trap. The exhaust steam is often insufficient to supply the entire heating system and must be supplemented by live steam taken directly from the boiler. This must first pass through a reducing valve in order to reduce the pressure to correspond with that carried in the heating system.

The exhaust steam discharged from non-condensing engines contains from 20 to 30 per cent of water, and considerable oil or greasy matter which has been employed for lubrication. When the engine is exhausting into the air, the pressure in the exhaust pipe is but slightly above that due to the atmosphere. The effect of passing exhaust steam through the pipes and radiators of a heating system is likely to increase the back pressure on the engine and reduce its effective work; this must be offset by raising the boiler pressure or increasing the cut-off of the engine.

An engine does not deliver steam continuously but at regular intervals at the end of each stroke and the amount is likely to vary with the work done since the governor is adjusted to admit steam in such a quantity as is required to maintain a uniform speed. If the work is light, very little steam will be admitted to the engine and for this reason the supply available for heating may

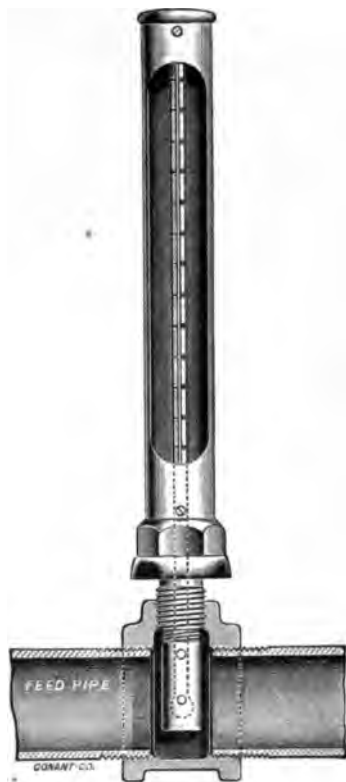


Fig. 52.

vary somewhat depending upon the use made of the power delivered by the engine. In mills the amount of exhaust steam is practically constant; in office buildings where power is used for lighting, the variation is greater, especially if power is also required for the running of elevators.

The general requirements for a successful system of exhaust steam heating include a system of piping of such proportions that only a slight increase in back pressure will be thrown upon the engine; a connection which shall automatically supply live steam at a reduced pressure as needed; provision for removing the oil from the exhaust steam; a relief or back pressure valve

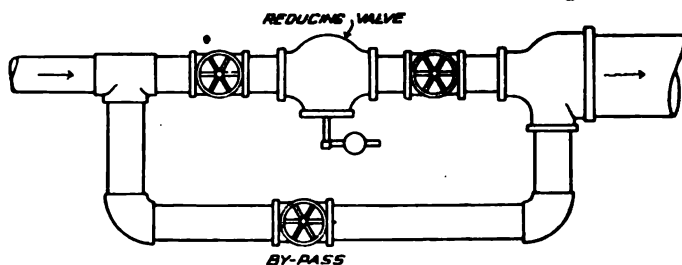
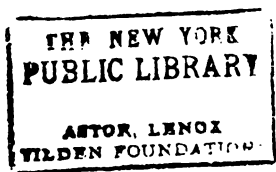


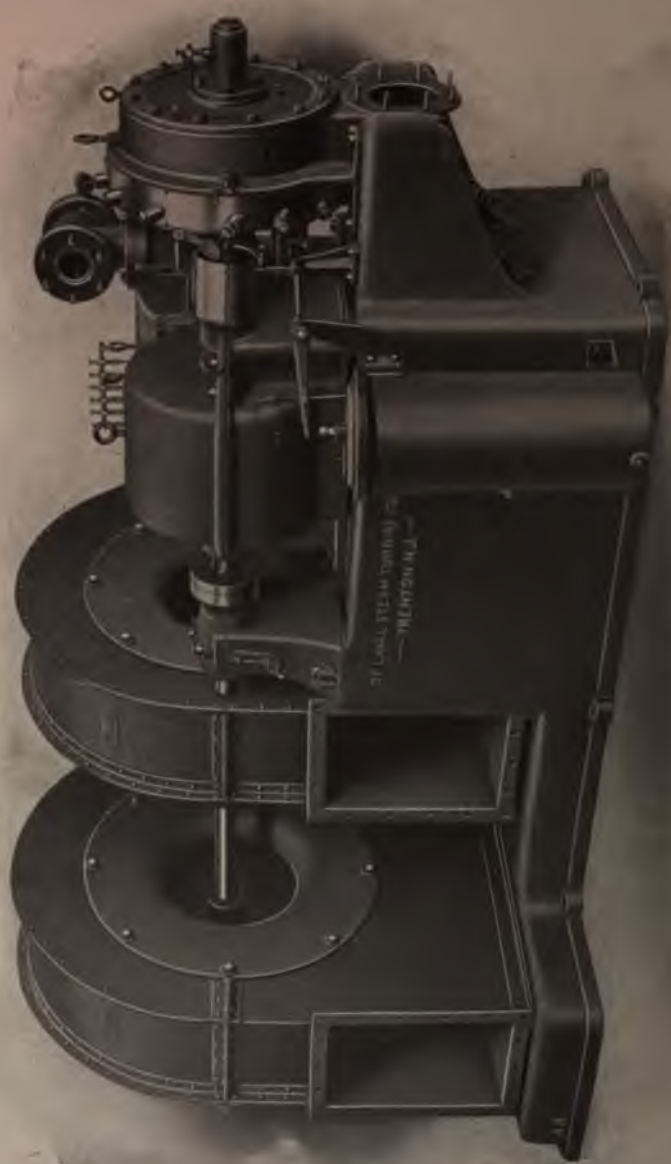
Fig. 53.

arranged to prevent any sudden increase in back pressure on the engine, and a return system of some kind for returning the water of condensation back to the boiler against a higher pressure. These requirements may be met in various ways depending upon actual conditions found in different cases.

To prevent sudden changes in the back pressure due to irregular supply of steam, the exhaust pipe from the engine is often carried to a closed tank having a capacity from 30 to 40 times that of the engine cylinder. This tank may be provided with baffle plates or other arrangements and serve as a separator for removing the oil from the steam as it passes through.

Any system of piping may be used but great care should be taken that as little resistance as possible is introduced at bends and fittings; and the mains and branches should be of ample size. Usually the best results are obtained from the system in which the main steam pipe is carried directly to the top of the building, the distributing pipes run from that point, and the radiating surfaces supplied by a down-flowing current of steam.





150 H.P. DE LAVAL TURBINE BLOWER.

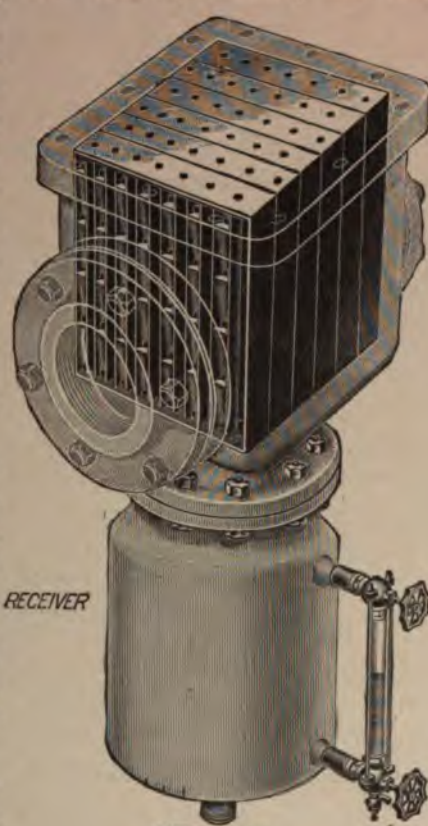
Before taking up the matter of piping in detail a few of the more important pieces of apparatus will be described in a brief way.

Reducing Valves. The action of pressure reducing valves has been taken up quite fully in "Boiler Accessories," and need not be repeated here. When the reduction in pressure is large, as in the case of a combined power and heating plant, the valve may be one or two sizes smaller than the low pressure main into which it discharges. For example—a 5-inch valve will supply an 8-inch main, a 4-inch a 6-inch main, a 3-inch a 5-inch main, a 2½-inch a 4-inch main, etc.

For the smaller sizes the difference should not be more than one size. All reducing valves should be provided with a valved by-pass for cutting out the valve in case of repairs. The connection is usually made as shown in plan by Fig. 53.

Grease Extractor. As already stated, when exhaust steam is used for heating purposes, it must first be passed through some form of separator for removing the oil. This is usually effected by introducing a series of baffling plates in the path of the steam; the particles of oil striking these are stopped and thus separated from the steam. The oil drops into a receiver provided for this purpose and is discharged through a trap to the sewer.

In the separator, or extractor, shown in Fig. 54, the separa-



DISCHARGE
Fig. 54.

tion is accomplished by a series of plates placed in a vertical position in the body of the separator through which the steam must pass. These plates consist of upright hollow columns, with openings at regular intervals for the admission of water and oil, which drains downward to the receiver below. The steam takes a zig-zag course and all of it comes in contact with the intercepting plates, which insures a thorough separation of the oil and other solid matter from the steam. Another form, shown in Fig. 55, gives excellent results and has the advantage of providing an equalizing chamber for overcoming, to some extent, the unequal pressure due to the varying load on the engine. It consists of a

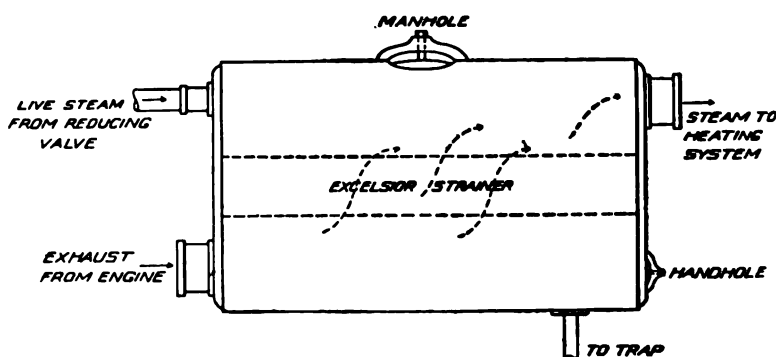


Fig. 55.

tank or receiver about 4 feet in diameter, with heavy boiler iron heads slightly crowned to give stiffness. Through the center is a layer of excelsior (wooden shavings of long fibre) about 12 inches in thickness, supported on an iron grating, with a similar grating laid over the top to hold it in place. The steam enters the space below the excelsior and passes upward, as shown by the arrows. The oil is caught by the excelsior which can be renewed from time to time as it becomes saturated. The oil and water which fall to the bottom of the receiver are carried off through a trap. Live steam may be admitted through a reducing valve for supplementing the exhaust when necessary.

Back Pressure Valve. This is a form of relief valve which is placed in the outboard exhaust pipe to prevent the pressure in the heating system from rising above a given point. Its office is the reverse of the reducing valve which supplies more steam when

the pressure becomes too low. The form shown in Fig. 56 is designed for a vertical pipe. The valve proper consists of two discs of unequal area, the combined area of which equals that of the pipe. The force tending to open the valve is that due to the steam pressure acting on an area equal to the difference in area between the two discs; it is clear from the cut that the pressure acting on the larger disc tends to open the valve while the pressure on the smaller acts in the opposite direction. The valve stem is connected by a link and crank arm with a spindle upon which is a lever and weight outside. As the valve opens the weight is raised so that by placing it in different positions on the lever arm the valve will open at any desired pressure.

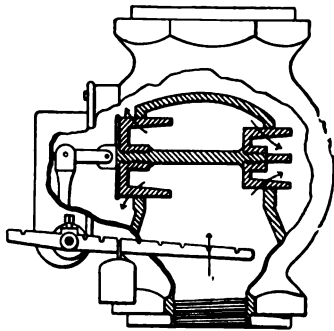


Fig. 56.

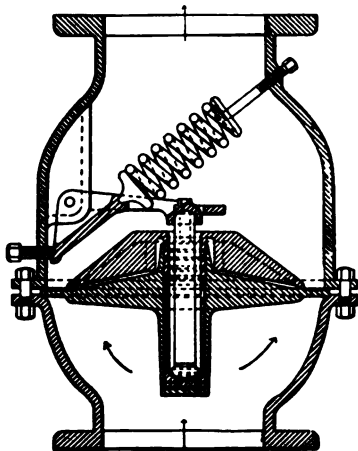


Fig. 57.

Fig. 57 shows a different type in which a spring is used instead of a weight. This valve has a single disc moving in a vertical direction. The valve stem is in the form of a piston or dash-pot which prevents a too sudden movement and makes it more quiet in its action. The disc is held on its seat against the steam pressure by a lever attached to the spring as shown. When the pressure of the steam on the underside becomes

greater than the tension of the spring, the valve lifts and allows the steam to escape. The tension of the spring can be varied by means of the adjusting screw at its upper end.

A back pressure valve is simply a low pressure safety valve designed with a specially large opening for the passage of steam through it. They are also made for horizontal pipes as well as vertical.

Exhaust Head. This is a form of separator placed at the top of an outboard exhaust pipe to prevent the water carried up in the steam from falling upon the roofs of buildings or in the street below. Fig. 58 is known as a centrifugal exhaust head. The steam on entering at the bottom is given a whirling or rotary motion by the spiral deflectors and the water is thrown outward by centrifugal force against the sides of the chamber from which it flows into the shallow trough at the base and is carried away through the drip pipe which is brought down and connected with

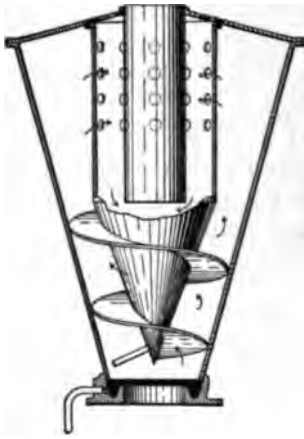


Fig. 58.

a drain pipe inside the building. The passage of the steam outboard is shown by the arrows. Other forms are used in which the water is separated from the steam by deflectors which change the direction of the currents.

Automatic Return Pumps. In exhaust heating plants the condensation is returned to the boilers by means of some form of return pump. A combined pump and receiver of the form illustrated in Fig. 59 is generally used. This consists of a cast or wrought iron tank mounted on a base in connection with a boiler feed pump. Inside of the tank is a ball float connected by means of levers with a valve in the steam pipe which is connected with the pump. When the water line in the tank rises above a certain level, the float is raised and opens the steam valve which starts the pump. When the water is lowered to its normal level the valve closes and the pump stops. By this arrangement a constant water line is maintained in the receiver and the pump runs only as needed to care for the condensation as it returns from the heating system. If dry returns are used they may be brought together and connected with the top of the receiver. If it is desired to seal the horizontal runs, as is usually the case, the receiver may be raised to a height sufficient to give the required elevation and the returns connected near the bottom below the water line.

A "balance pipe," so called should connect the heating main

with the top of the tank for equalizing the pressure, otherwise the steam above the water would condense and the vacuum thus formed would draw all the water into the tank leaving the returns practically empty and thus destroying the condition sought. Sometimes an independent regulator or pump governor is used in place of a receiver. One type is shown in Fig. 60. The return

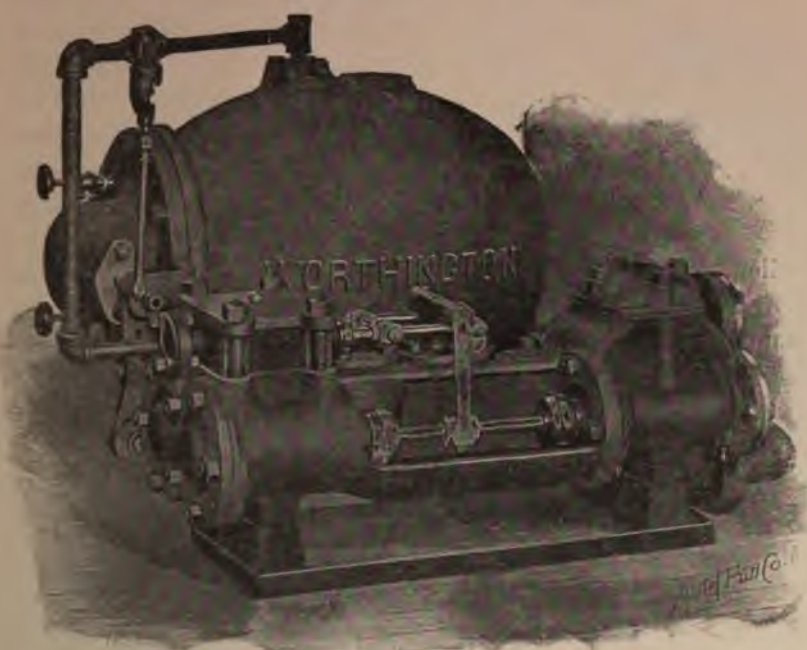


Fig. 59.

main is connected at the upper opening and the pump suction with the lower. A float inside the chamber operates the steam valve shown at the top and the pump works automatically as in the case just described.

If it is desired to raise the water line the regulator may be elevated to the desired height and connections made as shown in Fig. 61.

Return Traps. The principle of the return trap has been described in "Boiler Accessories" but its practical form and application will be taken up here. The type shown in Fig. 62 has all

of its working parts outside of the trap. It consists of a cast iron bowl pivoted at G and H. There is an opening through G connecting with the inside of the bowl.

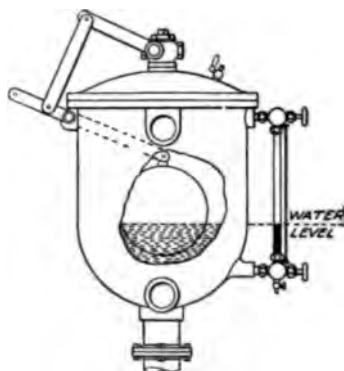


Fig. 60.

The pipe K connects through C with an interior pipe opening near the top (see Fig. 63.) The pipe D connects with a receiver into which all of the returns are brought. A is a check valve allowing water to pass through in the direction shown by the arrow. E is a pipe connecting with the boiler below the water line. B is a check opening toward the boiler and K a pipe connected with the steam main or drum.

The action of the trap is as follows. As the bowl fills with water from the receiver it overbalances the weighted lever and

The action of the trap is as follows. As the bowl fills with water from the receiver it overbalances the weighted lever and

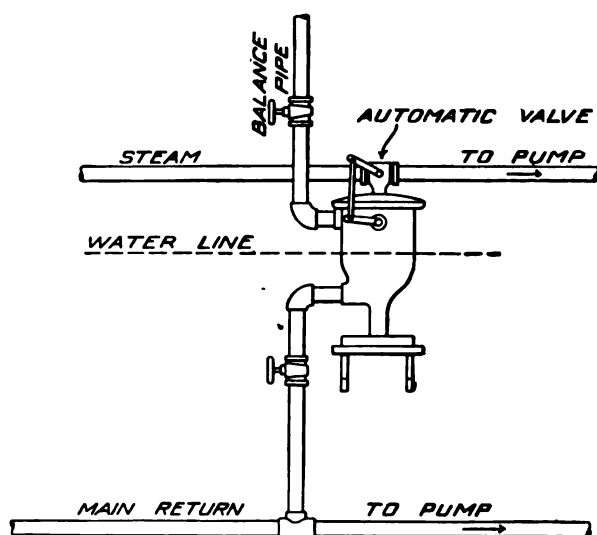


Fig. 61.

drops to the bottom of the ring. This opens the valve C and admits steam at boiler pressure to the top of the trap. Being at a higher level the water flows by gravity into the boiler, through

the pipe E. Water and steam are kept from passing out through D by the check A.

When the trap has emptied itself the weight of the ball raises it to the original position, which movement closes the valve C and opens the small vent F. The pressure in the bowl being relieved, water flows in from the receiver through D until the trap is filled, when the process is repeated. In order to work satisfactorily the trap should be placed at least 3 feet above the water level in the boiler and the pressure in the returns must always be sufficient to raise the water from the receiver to the trap against atmospheric pressure which is theoretically about 1 pound for every 2 feet in height. In practice there will be more or less friction to overcome, and suitable adjustments must be made for each particular case. Fig. 64 shows another form acting upon the same

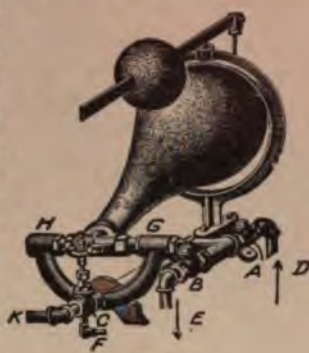


Fig. 62.



Fig. 63.

principle except in this case the steam valve is operated by a bucket or float inside of the trap. The pipe connections are practically the same as with the trap just described.

Return traps are more commonly used in smaller plants where it is desired to avoid the expense and care of a pump.

Damper Regulators. Every heating and every power plant should be provided with automatic means for closing the dampers when the steam pressure reaches a certain point, and for opening them again when the pressure drops. There are various regulators

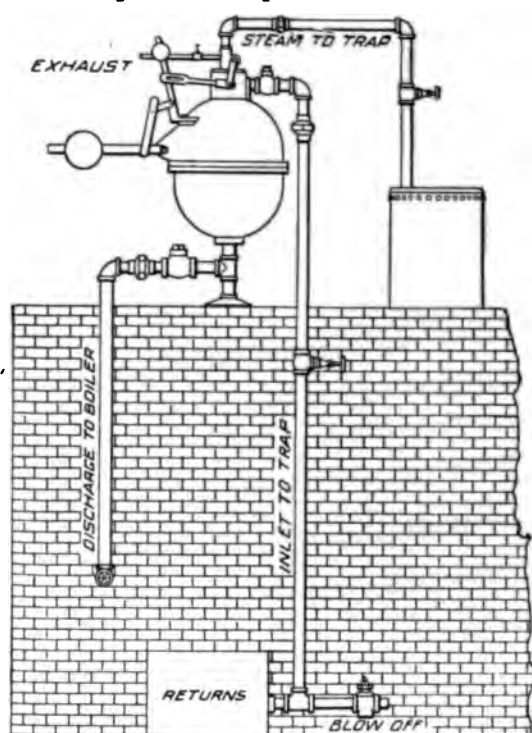


Fig. 64.

designed for this purpose, a simple form of which is shown in Fig. 65.

Steam at boiler pressure is admitted beneath a diaphragm which is balanced by a weighted lever. When the pressure rises to a certain point it raises the lever slightly and opens a valve which admits water under pressure above a diaphragm located near the smokepipe. This action forces down a lever connected by chains with the damper and closes it. When the steam pressure drops, the water valve is closed, and the different parts of the

apparatus take their original positions. Another form similar in principle is shown in Fig. 66. In this case a piston is operated by the water pressure instead of a diaphragm. In both types the pressures at which the damper shall open and close are regulated by suitable adjustments of the weights upon the levers.

Pipe Connections. The method of making the pipe connections in any particular case will depend upon the general arrange-

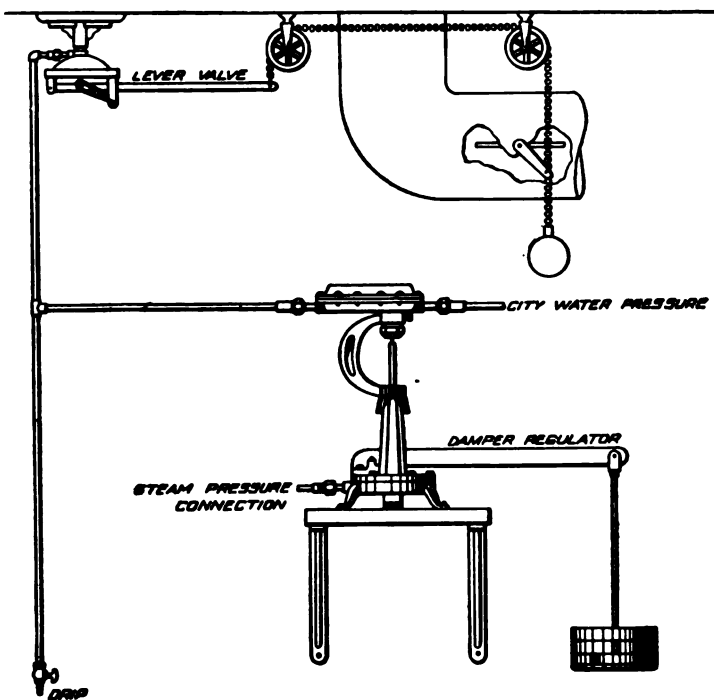


Fig. 65.

ment of the apparatus and the various conditions. Fig. 67 illustrates the general principles to be followed, and by suitable changes may be used as a guide in the design of new systems.

Steam first passes from the boilers into a large drum or header; from this a main, provided with a shut-off valve, is taken as shown; one branch is carried to the engines while another is connected with the heating system through a reducing valve having a by-pass and cut-out valves. The exhaust from the engines connects with the large main over the boilers at a point just above

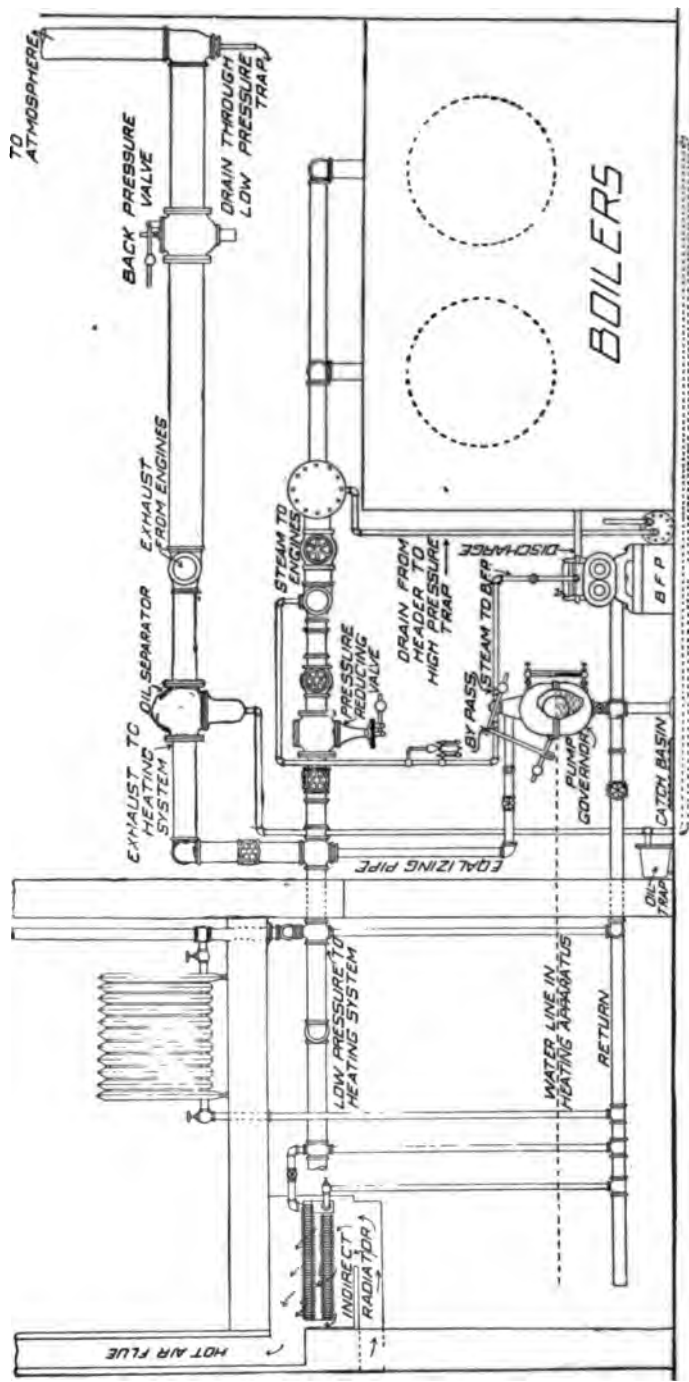


Fig. 67.

the steam drum. The branch at the right is carried outboard through a back pressure valve which may be set to carry any desired pressure on the system. The other branch at the left passes through an oil separator into the heating system. The connections between the mains and radiators are made in the usual way and the main return is carried back to the return pump near the floor. A false water line or seal is obtained by elevating

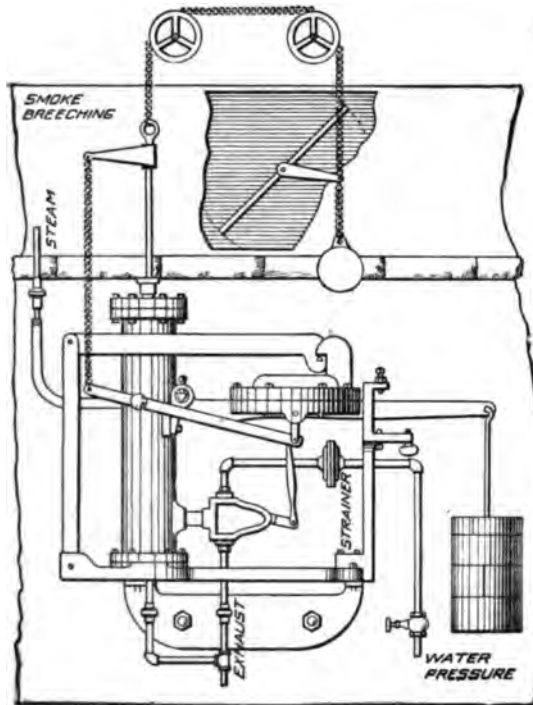


Fig. 66.

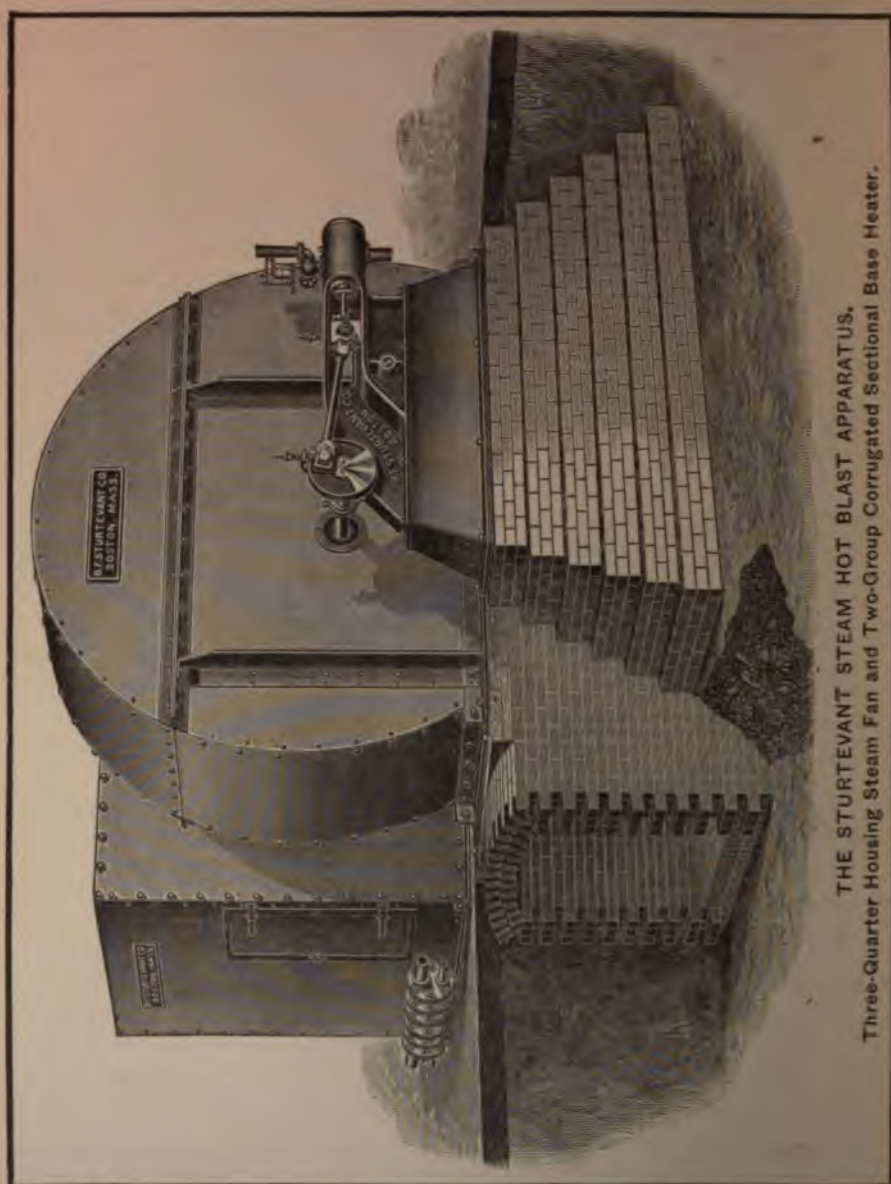
the pump regulator as already described. An equalizing or balance pipe connects the top of the regulator with the low pressure heating main and high pressure is supplied to the pump as shown.

A sight feed lubricator should be placed in this pipe above the automatic valve, and a valved by-pass should be placed around the regulator for running the pump in case of accident or repairs. The oil separator should be drained through a special oil trap to a

catch basin or to the sewer, and the steam drum or any other low points or pockets in the high pressure piping dripped to the main return through suitable traps.

Means should be provided for draining all parts of the system to the sewer and all traps and special apparatus should be bypassed. The return pump should always be duplicated in a plant of any size as a safeguard against accident and the two pumps run alternately to make sure that one is always in working order. One piece of apparatus not shown in Fig. 67 is the feed water heater. If all of the exhaust steam can be utilized for heating purposes, this is not necessary as the cold water for feeding the boilers may be discharged into the return pipe and be pumped in with the condensation. In summer time, however, when the heating plant is not in use, a feedwater heater is necessary, as a large amount of heat which would otherwise be wasted may be saved in this way. The connections will depend somewhat upon the form of heater used, but in general a single connection with the heating main inside the back pressure valve is all that is necessary. The condensation from the heater should be trapped to the sewer.





THE STURTEVANT STEAM HOT BLAST APPARATUS.
Three-Quarter Housing Steam Fan and Two-Group Corrugated Sectional Base Heater.

HEATING AND VENTILATION.

PART III.

VACUUM SYSTEMS.

Low Pressure or Vacuum Systems. In the systems of steam heating which have been described up to this point the pressure carried has always been above that of the atmosphere, and the action of gravity has been depended upon to carry the water of condensation back to the boiler or receiver; the air in the radiators has been forced out through air valves by the pressure of steam back of it. Methods will now be taken up in which the pressure

in the heating system is less than the atmosphere and where the circulation through the radiators is produced by suction rather than by pressure. Systems of this kind have several advantages over the ordinary methods of circulation under pressure. First — no back pressure is produced at the engines when used in connection with exhaust steam, but rather there will be a reduction of pressure due to the partial vacuum existing in the radiators; second — a complete re-

moval of air from the coils and radiators so that all portions are steam filled and available for heating purposes; third — complete drainage through the returns, especially those having long horizontal runs, and the absence of water hammer; and fourth the smaller size of return pipes necessary. The two systems of this kind in most common use are known as the Webster and Paul systems.

Webster System. This consists primarily of an automatic outlet valve on each coil and radiator connected with some form of suction apparatus such as a pump or ejector. The valve used is shown in section in Fig. 1 and replaces the usual hand valve at

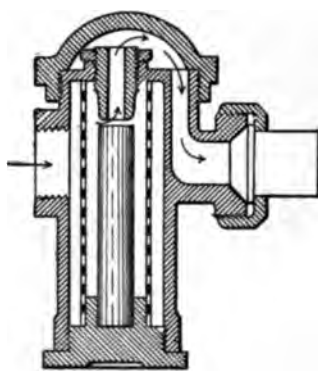


Fig. 1.

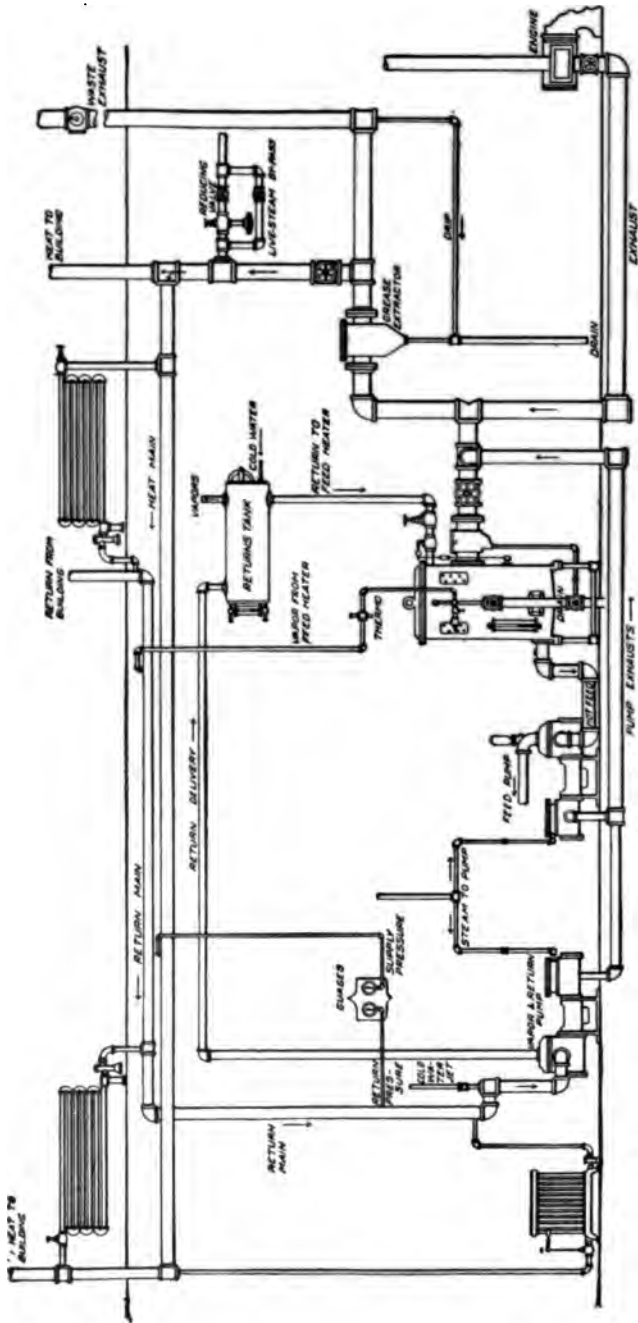


Fig. 4.

the return end of the radiator. It is similar in construction to some of the air valves already described, consisting of a rubber or vulcanite stem closing against a valve opening when made to expand by the presence of steam. When water or air fills the valve the stem contracts and allows them to be sucked out as shown by the arrows. A perforated metal strainer surrounds the stem or expansion piece to prevent dirt and sediment from clogging the valve.

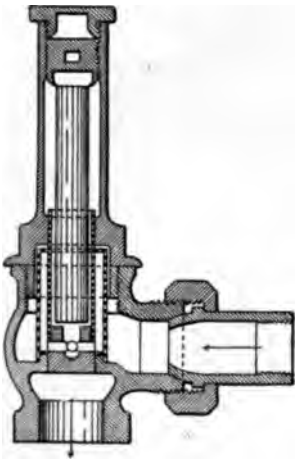


Fig. 2.

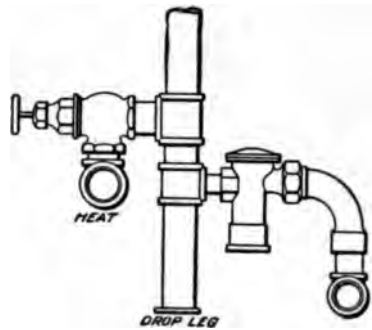


Fig. 3.

Fig. 2 shows the valve, or thermostat as it is called, attached to an ordinary angle valve with the top removed, and Fig. 3 indicates the method of draining the bottoms of risers or the ends of mains.

One special advantage claimed for this system is that the amount of steam admitted to the radiators may be regulated to suit the requirements of outside temperature, and this may be done without water logging or hammering, a result impossible to obtain with any other combination of steam heating apparatus. This may be done at will by closing down on the inlet supply to the desired degree. The result is the admission of a smaller amount of steam to the radiator than it is calculated to condense normally. The condensation is removed as fast as formed by the opening of the thermostatic valve.

The general application of this system to exhaust heating is shown in Fig. 4. Exhaust steam is brought from the engine as shown; one branch is connected with a feed-water heater while the other is carried upward and through a grease extractor where it branches again, one line leading outbound through a back-pressure valve and the other connecting with the heating main. A live steam connection is made through a reducing valve as in the ordinary system. Valved connections are made with the coils and radiators in the usual manner but the return valves are replaced by the special thermostatic valves described above.

The main return is brought down to a vacuum pump which discharges into a "returns tank" where the air is separated from the water and passes off through the vapor pipe at the top. The condensation then flows into the feed water heater from which it is automatically pumped back into the boilers. The cold-water feed supply is connected with the returns tank and a small cold-water jet is connected into the suction at the vacuum pump for increasing the vacuum in the heating system by the condensation of steam at this point.

Paul System. In this system the suction is connected with the air valves instead of the returns and the vacuum is produced by means of a steam ejector instead of a pump. The returns are carried back to a receiving tank and pumped back to the boiler in the usual manner. The ejector in this case is called the "exhauster."

Fig. 5 shows the general method of making the pipe connections with radiators in this system and Fig. 6 the details of connection at the exhauster.

A A are the returns from the air valves and connect with the exhausters as shown. Live steam is admitted in small quantities through the valves B B and the mixture of air and steam is discharged outboard through the pipe C. D D are gages showing the pressure in the system and E E are check valves. The advantage of this system depends principally upon the quick removal of air from the various radiators and pipes which constitutes the principal obstruction to circulation; the inductive action in many cases is sufficient to cause the system to operate somewhat below atmospheric pressure.

Where exhaust steam is used for heating, the radiators should be somewhat increased in size owing to the lower temperature of

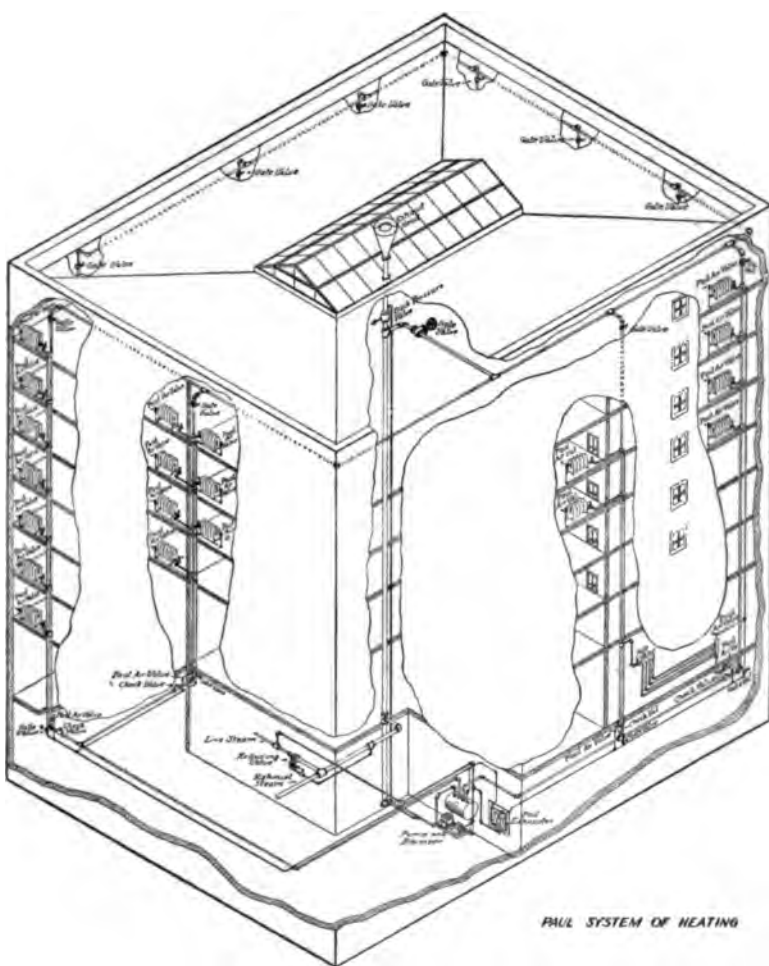


Fig. 6.

the steam. It is common practice to add from 20 to 30 per cent to the sizes required for low pressure live steam.

FORCED BLAST.

In a system of forced circulation by means of a fan or blower the action is positive and practically constant under all usual conditions of outside temperature and wind action. This gives it a decided advantage over natural or gravity methods which are affected to a greater or less degree by changes in wind pressure,

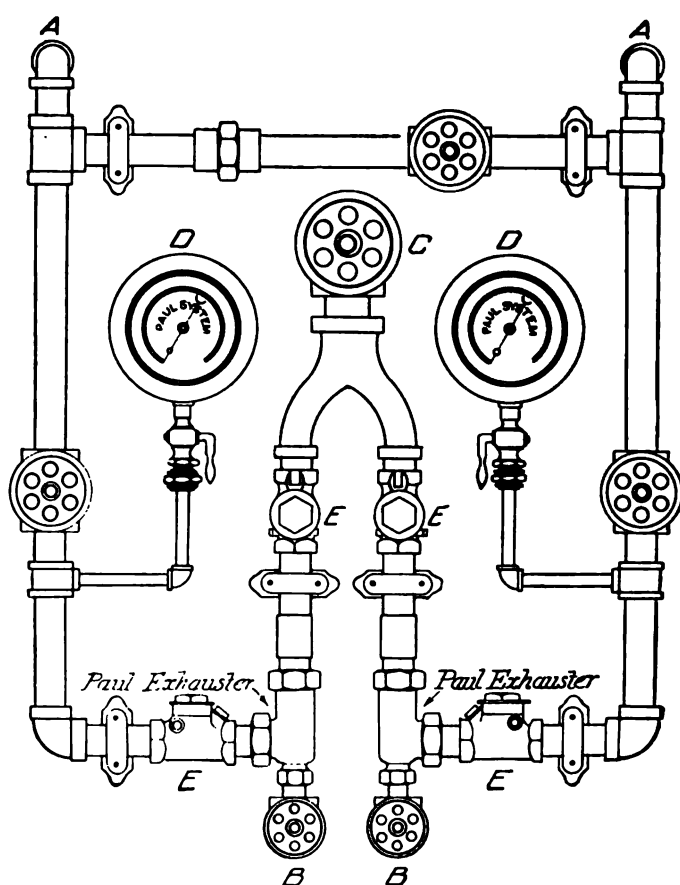


Fig. 6.

and makes it especially adapted to the ventilation and warming of large buildings such as shops, factories, schools, churches, halls, theatres, etc., where large and definite air quantities are required.

Exhaust Method. This consists in drawing the air out of a building and providing for the heat thus carried away by placing steam coils under windows or in other positions where the inward leakage is supposed to be the greatest. When this method is used a partial vacuum is created within the building or room and

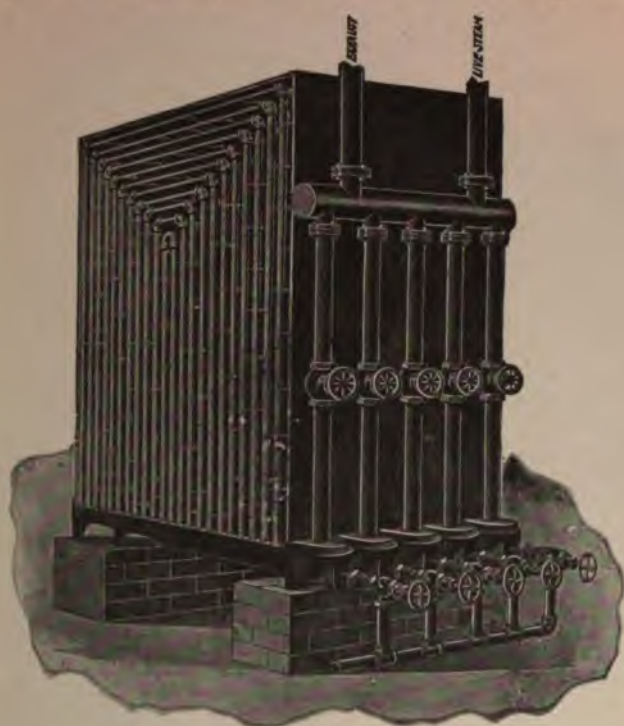


Fig. 7.

all currents and leaks are inward; there is nothing to govern definitely the quality and place of introduction of the air, and it is difficult to provide suitable means for warming it.

Plenum Method. In this case the air is forced into the building, and its quality, temperature and point of admission are completely under control. All spaces are filled with air under a slight pressure and the leakage is outward, thus preventing the drawing of foul air into the room from any outside source. But above all, ample opportunity is given for properly warming the

air by means of heaters, either in direct connection with the fan or in separate passages leading to the various rooms.

Form of Heating Surface. A common form of heater for

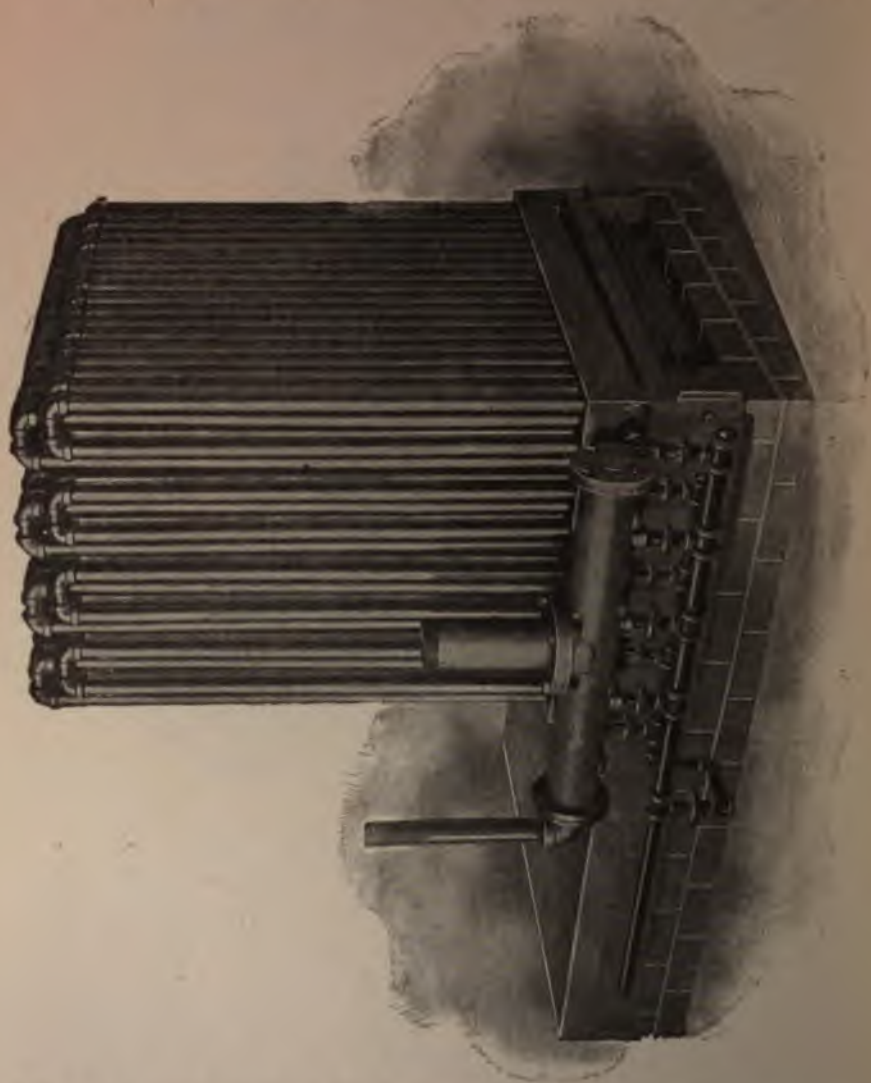


FIG. 16.

forced blast heating is shown in Fig. 16, Part I. This consists of sectional cast-iron bases with loops of wrought-iron pipe connected as shown. The steam enters the upper part of the bases or

headers and passes up one side of the loops, then across the top and down on the other side where the condensation is taken off through the return drip, which is separated from the inlet by a partition. These heaters are made up in sections of 2 and 4 rows of pipes each. The height varies from $3\frac{1}{2}$ to 9 feet and the width from 3 feet to 7 feet in the standard sizes. They are usually made up of 1-inch pipe although $1\frac{1}{4}$ inch is commonly used in the larger sizes. In Fig. 7 is shown a similar heater. This is arranged for supplying exhaust to a portion of the sections and live steam to the remainder. The division between the two sections is shown where the metal is broken away. Fig. 8 shows still

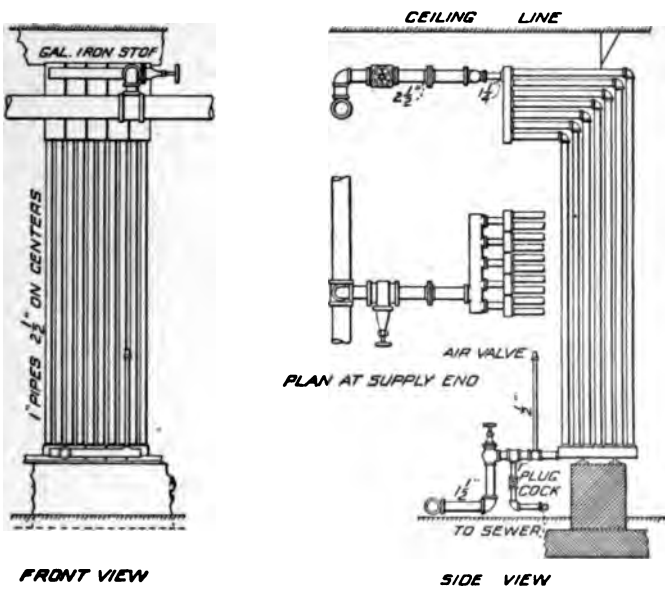


Fig. 9.

another form; in this case all of the loops are made of practically the same length by the special form of construction shown. This is claimed to prevent the short circuiting of steam through the shorter loops which causes the outer pipes to remain cold.

This form of heater is usually encased in a sheet steel housing as shown, but may be supported on a foundation between brick walls if desired.

Fig. 9 shows a special form of heater particularly adapted to ventilating work where the air does not have to be raised above

70 or 80 degrees. It is made up of 1-inch wrought-iron pipe connected with supply and return headers: each section contains 14 pipes and they are usually made up in groups of 5 sections each. These coils are supported upon tee irons resting upon a brick foundation. Heaters of this form are usually made to extend across the side of a room with brick walls at the sides instead of being encased in steel housings. Heaters made up of banks of the school-pin cast-iron radiators give excellent results for schoolhouse work. The sections should be so arranged that the free area for air flow shall not be too much restricted.

Efficiency of Heaters. The efficiency of the heaters used in connection with forced blast varies greatly, depending upon the temperature of the entering air, its velocity between the pipes, the temperature to which it is raised and the steam pressure carried in the heater. The general method in which the heater is made up is also an important factor.

In designing a heater of this kind, care must be taken that the free area between the pipes is not contracted to such an extent that an excessive velocity will be required to pass the given quantity of air through it. In ordinary work it is customary to assume a velocity of 800 to 1000 feet per minute; higher velocities call for a greater pressure on the fan which is not desirable in ventilating work.

In the heaters shown, about .4 of the total area is free for the passage of air; that is, a heater 5 feet wide and 6 feet high would have a total area of $5 \times 6 = 30$ square feet, and a free area between the pipes of $30 \times .4 = 12$ square feet. The depth or number of rows of pipe does not effect the free area although the friction is increased and additional work is thrown upon the fan. The efficiency in any given heater will be increased by increasing the velocity of the air through it, but the final temperature will be diminished, that is, a larger quantity of air will be heated to a lower temperature in the second case and while the total heat given off is greater, the air quantity increases more rapidly than the heat quantity which causes a drop in temperature.

Increasing the number of rows of pipe in a heater with a constant air quantity increases the final temperature of the air but diminishes the efficiency of the heater, because the average differ

ence in temperature between the air and steam is less. Increasing the steam pressure in the heater (and consequently its temperature) increases both the final temperature of the air and the efficiency of the heater. Table I has been prepared from different tests and may be used as a guide in computing probable results under ordinary working conditions. In this table it is assumed that the air enters the heater at a temperature of 10 degrees below zero and passes between the pipes with a velocity of 800 feet per minute. Column 1 gives the number of rows of pipe in the heater and columns 2, 3 and 4 the final temperature of the air for different steam pressures. Columns 5, 6 and 7 give the corresponding efficiency of the heater.

For example. Air passing through a heater 10 pipes deep and carrying 20 pounds pressure will be raised to a temperature of 90 degrees and the heater will have an efficiency of 1650 B.T.U. per square foot of surface per hour. When the air is taken in at zero we may add 10 to the final temperatures given in the table, although theoretically it would be slightly less; in this case we must take the efficiency corresponding to the final temperature after the 10 degrees have been added.

TABLE I.

Temp. of entering air 10° below zero.

Velocity of air between the pipes 800 feet per minute.

Rows of pipe deep.	Temp. to which the air will be raised from 10° below 0.			Efficiency of the heating surface in B. T. U., per square foot per hour.		
	Steam Pressure in Heater.			Steam Pressure in Heater.		
	5 lbs.	20 lbs.	60 lbs.	5 lbs.	20 lbs.	60 lbs.
4	30	35	45	1600	1800	2000
6	50	55	65	1600	1800	2000
8	65	70	85	1500	1650	1850
10	80	90	105	1500	1650	1850
12	95	105	125	1500	1650	1850
14	105	120	140	1400	1500	1700
16	120	130	150	1400	1500	1700
18	130	140	160	1300	1400	1600
20	140	150	170	1300	1400	1600

For a velocity of 1000 feet, multiply the *temperatures* given in the table by .95 and the *efficiencies* by 1.13.

Example. How many square feet of radiation will be required to raise 600,000 cubic feet of air per hour from 10 below zero to 80 degrees, with a velocity through the heater of 800 feet per minute and a steam pressure of 5 pounds? What must be the total area of the heater front and how many rows of pipes must it have?

Referring back to our formula for heat required for ventilation, we have

$$\frac{600,000 \times 90}{55} = 981,818 \text{ B. T. U. required.}$$

Referring to table I we find that for the above conditions a heater 10 pipes deep is required, and that an efficiency of 1500 B. T. U. will be obtained. Then $\frac{981,818}{1500} = 654$ square feet of

surface required, $\frac{600,000}{60} = 10,000$ cubic of air per minute, and

$\frac{10,000}{800} = 12.5$ square feet of free area required through the heater. If we assume .4 of the total heater front to be free for the passage of air, then $\frac{12.5}{.4} = 31$ the required total area.

For convenience in estimating the approximate dimensions of a heater, the following table is given. The standard heaters made by different manufacturers vary somewhat, but the dimensions given below represent average practice. Column 3 gives the square feet of heating surface in a single row of pipes of the dimensions given in columns 1 and 2, and column 4 gives the free area between the pipes.

TABLE II.

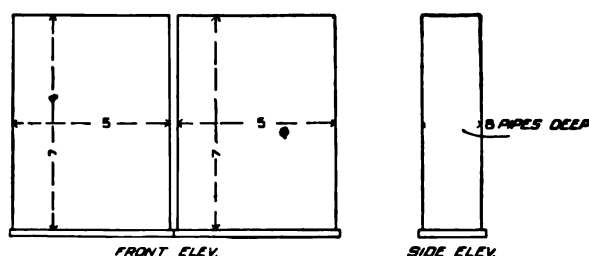
Width of Section.	Height of Pipes.	Square Feet of Surface.	Free Area through Heater in Sq. Ft.
3 feet	3 ft. 6 inches	20	4.2
3 feet	4 ft. 0 inches	22	4.8
3 feet	4 ft. 6 inches	25	5.4
3 feet	5 ft. 0 inches	28	6.0
4 feet	4 ft. 6 inches	34	7.2
4 feet	5 ft. 0 inches	38	8.0
4 feet	5 ft. 6 inches	42	8.8
4 feet	6 ft. 0 inches	45	9.6
5 feet	5 ft. 6 inches	52	11.0
5 feet	6 ft. 0 inches	57	12.0
5 feet	6 ft. 6 inches	62	13.0
5 feet	7 ft. 0 inches	67	14.0
6 feet	6 ft. 6 inches	75	15.6
6 feet	7 ft. 0 inches	81	16.8
6 feet	7 ft. 6 inches	87	18.0
6 feet	8 ft. 0 inches	92	19.2
7 feet	7 ft. 6 inches	98	21.0
7 feet	8 ft. 0 inches	108	22.4
7 feet	8 ft. 6 inches	109	23.8
7 feet	9 ft. 0 inches	116	25.2

In calculating the total height of the heater add 1 foot for the base.

These sections are made up of 1-inch pipe except the last, or 7-foot sections, which are made of $1\frac{1}{4}$ -inch pipe.

Using this table in connection with the example just given we should look in the last column for a section having a free area of 12.5 square feet; here we find that a 5 feet $\times$ 6 feet — 6 inches section has a free opening of 13 square feet and a radiating surface of 62 square feet. The conditions call for 10 rows of pipes and $10 \times 62 = 620$ square feet of radiating surface which is slightly less than called for, but which would be near enough for all practical purposes.

As a further example, if we compute the dimensions of a heater to warm 20,000 cubic feet of air per minute from 10 degrees below zero to 70 degrees above, with 20 pounds steam, we find that 1057 square feet of surface will be required. The heater must be 8 pipes deep and requires 25 square feet of free area. These may be obtained by 16 $5' \times 7'$ sections side by side, as in the sketch. These will give 28 square feet of free area and 1072 square feet of surface.



The general method of computing the size of heater for any given building is the same as in the case of indirect heating: First obtain the B.T.U. required for ventilation and to that add the heat loss through walls, etc., and divide the result by the efficiency of the heater under the given conditions.

Example.—An audience hall is to be provided with 400,000 cubic feet of air per hour. The heat loss through walls, etc., is 250,000 B.T.U. per hour in zero weather. What will be the size of heater, and how many rows of pipe deep must it be, with 20 pounds steam pressure.

$$\frac{400,000 \times 70}{55} = 509,090 \text{ B.T.U. for ventilation.}$$

Therefore $250,000 + 509,090 = 759,090$ B.T.U., total to be supplied.

We must next find to what temperature the entering air must be raised in order to bring in the required amount of heat, so that the number of rows of pipe in the heater may be obtained and its corresponding efficiency determined. We have entering the room for purposes of ventilation, 400,000 cubic feet of air every hour at a temperature of 70 degrees, and the problem now

becomes, to what temperature must this air be raised to carry in 250,000 B.T.U. additional for warming?

We have learned that 1 B.T.U. will raise 55 cubic feet of air 1 degree. Then 250,000 B.T.U. would raise $250,000 \times 55$ cubic feet of air 1 degree.

$$\frac{250,000 \times 55}{400,000} = 34 +$$

The air in this case must be raised to $70 + 34 = 104$ degrees to provide for both ventilation and warming. Referring to table I we find that a heater 12 pipes deep will be required and that the corresponding efficiency of the heater will be 1650 B.T.U.

$$\text{Then } \frac{759090}{1650} = 460 \text{ square feet of surface required.}$$

Pipe Connections. In the heater shown in Fig. 16, Part I, all of the sections take their supply from a common header; the supply pipe connecting with the top, and the return being taken from the lower division at the end, as shown.

In Fig. 7 the base is divided into two parts, one for live steam and the other for exhaust. The supply pipes connect with the upper compartments and the drips are taken off as shown. Separate traps should be provided for the two pressures.

The connections in Fig. 8 are similar to those just described except the supply and return headers, or bases, are drained through separate pipes and traps; there being a slight difference in pressure between the two which is likely to interfere with the proper drainage if brought into the same one. This heater is arranged to take exhaust steam but has a connection for feeding in live steam through a reducing valve if desired; the whole heater being under one pressure.

It is often desirable to have a heater connected up in sections so that one or more can be shut off in mild weather when the whole capacity of the heater is not required. In this case each section has separate connections with valves in supply and return. Fig. 10 shows an excellent method of making the connections for a heater using both live and exhaust steam as in this way any number of sections may be used for exhaust from one to the entire heater by a proper adjustment of the valves.

The usual connections in Fig. 9 are plainly shown. A supply header runs across the front of the heater from which valved branches are taken off to the several groups. The return pipes have cross connections with the sewer or drain for blowing out the air when steam is first turned on. Two or more groups should be connected for the use of either exhaust or live steam as shown in Fig. 10, and separate traps should be provided for the two pressures. Large and freely working automatic air valves

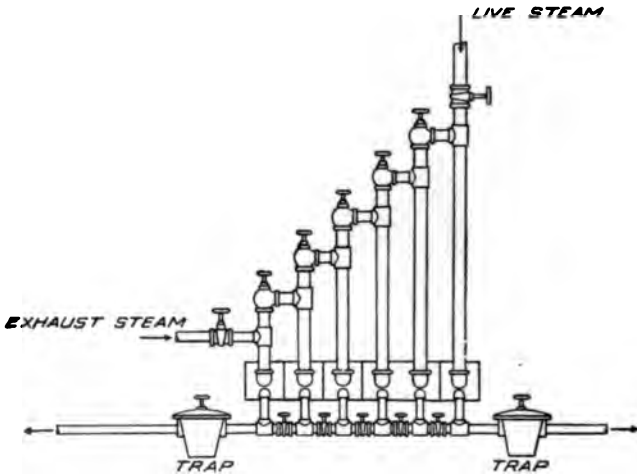


Fig. 10.

should be provided in the return header of each section or group, whatever the type of heater, and it is well also to provide hand pet cocks for opening when steam is first turned on. The form of heater shown in Fig. 9 is especially efficient and may be relied upon to give an efficiency of about 1800 B.T.U. and to raise the air from zero to 80° with a velocity of 800 feet between the pipes and a steam pressure of 20 pounds. A cast-iron sectional heater will give about 1500 B.T.U under the same conditions.

Pipe Sizes. The pipe sizes required in this system of heating may be computed from the tables already given. The length of run from the boiler or main, the pressure carried and the allowable drop are the factors governing the size of the main supply and branches. Heaters of the pattern shown in Figs. 7 and 10

are usually tapped at the factory for high or low pressure as desired and these sizes may be followed in making the pipe connections.

The sizes marked on Fig. 9 may be used for all ordinary work where the pressure runs from 5 to 20 pounds; for pressures above that the supply connections may be reduced one size.

Fans and Blowers.
The term fan is commonly applied to any form of apparatus for moving air in which revolving blades or

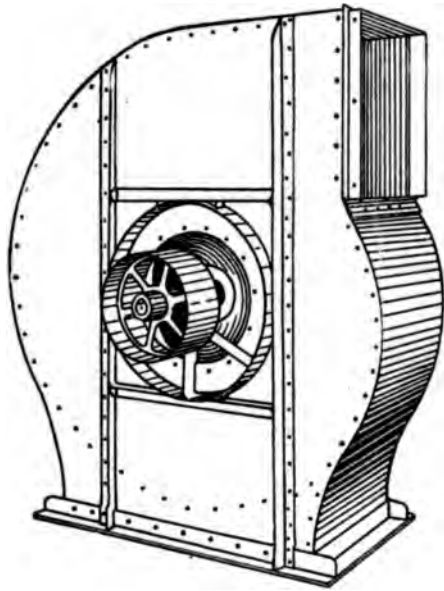


Fig. 11.

propellers are used, while the word blower is used only in those cases where the wheel or propeller is enclosed in a casing.

Referring to Part I, Fig. 17 shows the usual form of fan or wheel used in the common type of blower and Fig. 11 represents the usual form of a regular steel plate blower with full housing. Where a blower is connected with a heater having a steel plate casing it has an inlet only on one side,

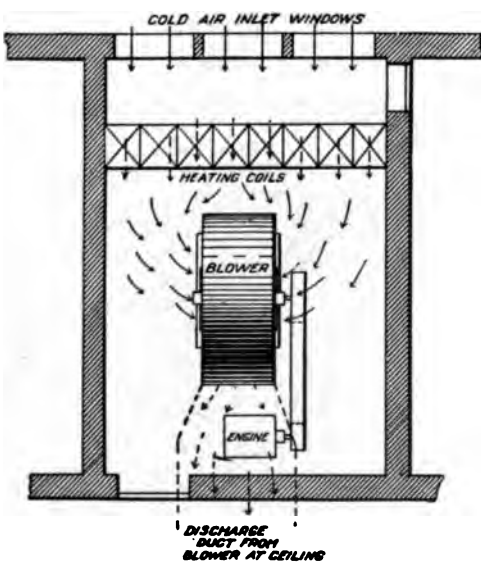


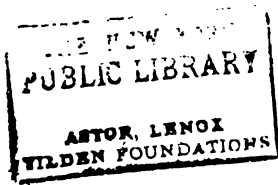
Fig. 12.

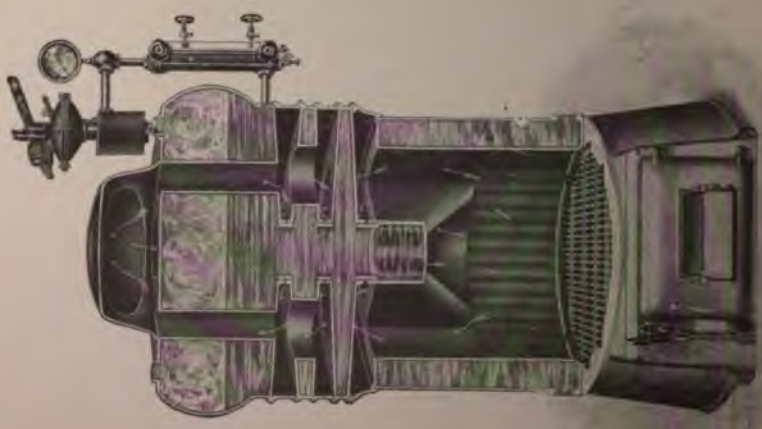
but when used in connection with a heater of the type shown in Fig. 9 it should have inlet openings upon both sides as shown in Fig. 12.



Fig. 13.

The discharge opening can be made in any position desired, either up, down, top horizontal, bottom horizontal or at any angle. Fig. 13 shows a top horizontal discharge blower connected with a heater.





VIEWS OF THE AMERICAN RADIATOR COMPANY'S STEAM BOILER FOR HARD COAL.

Where the height of the fan room is limited, a form called the three-quarter housing may be used in which the lower part of the casing is replaced by a brick pit below the floor level. Such a construction is shown in Fig. 14 with a direct-connected engine. Another type of fan known as a disc wheel may be used where the air passages are large and the resistance to air flow is small, but for ordinary ventilating work the encased blower is to be preferred. The cone fan shown in Fig. 20, Part I, is a very efficient



Fig. 14.

form and may be used in a wall opening as there shown or made double and enclosed in a steel plate housing.

Fan Capacity. The volume of air which a given fan will deliver depends upon the speed at which it is run and the friction or resistance through the heater and air ways. The pressure referred to in connection with a fan is that in the discharge outlet and represents the force which drives the air through the ducts and flues. The greater the pressure with a given resistance in the pipes the greater will be the volume of air delivered, and the greater the resistance, the greater the pressure required to deliver a given quantity.

Fan wheels of the same manufacture are usually made with a constant ratio between the diameter and width, although special

forms are made where this does not hold true. All practical data on the action of fans is based on the results of tests, and from these the following relations have been found to be approximately correct:

(1) The volume of air delivered varies *directly* as the speed of the fan, that is, doubling the number of revolutions doubles the volume of air delivered.

(2) The pressure varies as the *square* of the speed, for example, if the speed is doubled the pressure is increased $2 \times 2 = 4$ times, etc.

(3) The power required to run the fan varies as the *cube* of the speed; again, if the speed is doubled the power required is increased $2 \times 2 \times 2 = 8$ times.

The value of a knowledge of these relations may be illustrated by the following example.

Suppose for any reason it was desired to double the volume of air delivered by a certain fan. At first thought we might decide to use the same fan and run it twice as fast; but when we come to consider the power required we should find that this would have to be increased 8 times, and it would probably be much cheaper in the long run to put in a larger fan and run it at lower speed. In speaking of a fan as a 4 or 5-foot fan, the diameter of the propeller wheel is meant, but if we say an 80 or 100-inch fan we mean the height of casing in inches.

It has been found in practice that fans of the blower type having curved floats operate quietly and give good results when run at a speed corresponding to $\frac{1}{2}$ ounce pressure at the discharge outlet; this gives a speed of about 3600 feet per minute at the circumference of the wheel. Higher speeds are accompanied with a greater expenditure of power and are likely to produce a roaring noise or cause vibration. A much lower speed does not provide sufficient pressure to give proper control of the air distribution during strong winds. The following table gives average capacities for various sizes of fans and the corresponding horse-power of engine required. If an electric motor is used multiply the horse-power given in the table by 1.3.

This is done because we can never tell *exactly* what the power required will be and it is well to have an excess to meet any

emergency or unlooked-for conditions which may arise. In the case of a steam engine the steam pressure may be raised to meet any special requirements but a motor can only give out the original power for which it was designed.

TABLE III.

Nominal Size of Fan. Height of Housing in Inches.	Diameter of Fan Wheel in Inches.	Width of Housing in Inches.	Ordinary Speed Giving $\frac{1}{2}$ Ounce Pressure.	Cubic Feet of Air Delivered per Minute.	Horse-Power of Engine to Drive the Fan.
30	18	9	870	1000	$\frac{1}{2}$
40	24	12	580	1600	1
50	30	15	465	2600	1
60	36	18	390	4500	2
70	42	21	333	6000	$2\frac{1}{2}$
80	48	24	293	8000	$2\frac{1}{2}$
90	54	28	260	11000	$\frac{3}{4}$
100	60	32	233	12500	4
120	72	43	195	21500	7
140	84	48	167	28500	9
160	96	48	147	31800	10
	108	54	130	40400	13
	120	60	117	51000	16

Fan Engines. A simple, quiet running engine is desirable for use in connection with a fan or blower. They may be either horizontal or vertical and for schoolhouse and similar work should be provided with large cylinders so that the required power may be developed without carrying a boiler pressure much above 30 pounds. In some cases cylinders of such size are used that a boiler pressure of 12 or 15 pounds is sufficient. The quantity of steam which an engine consumes is of minor importance as the exhaust can be turned into the coils and used for heating purposes. If space allows, the engine should always be belted to the fan. Where it is direct-connected, as in Fig. 14, there is likely to be trouble from noise, as any slight looseness or pounding in the engine will be communicated to the air ducts and the sound will be carried to the rooms above. Figs. 15 and 16 show common forms of fan engines. The latter is especially adapted to this pur-

pose as all bearings are enclosed and protected from dust and grit. A horizontal engine for fan use is shown in Fig. 17.

Motors. Electric motors are especially adapted for use in

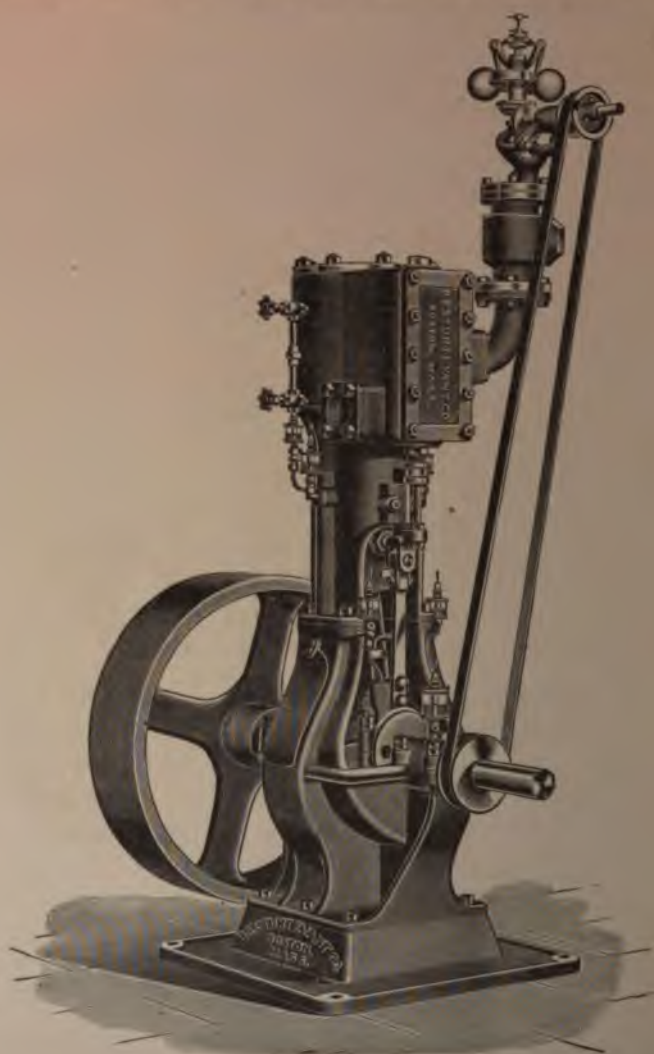


Fig. 15.

connection with fans. They are easily controlled by a switch and starting box or regulator. The motor may be directly connected

to the fan shaft or it may be belted. Fig. 18 shows a fan with direct-connected motor.

Area of Ducts and Flues. With the blower type of fan the size of the main ducts may be based on a velocity of 1200 to 1500 feet per minute, the branches on a velocity of 1000 to 1200 feet per minute, and as low as 600 to 800 feet when the pipes are small. Flue

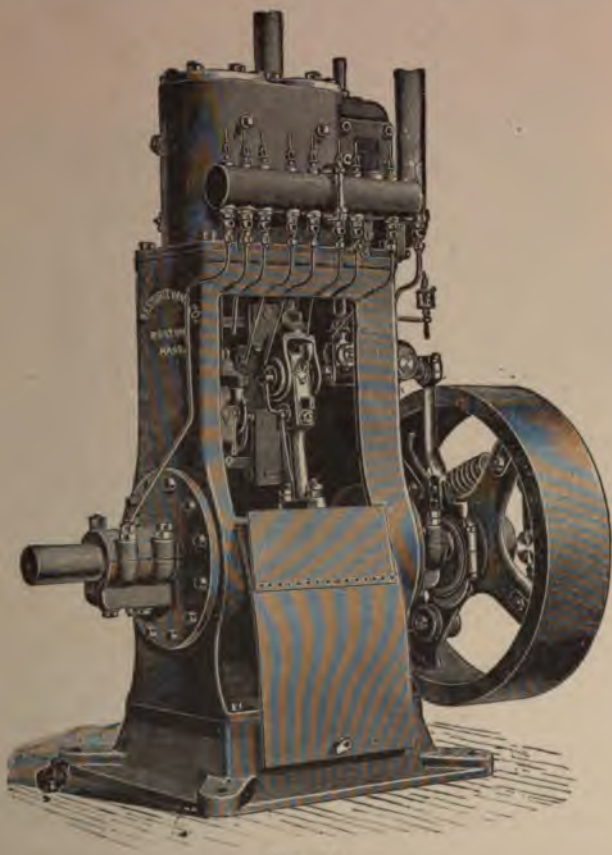


Fig. 18.

velocities of 500 to 700 feet per minute may be used although the lower velocity is preferable. The size of the inlet register should be such that the velocity of the entering air will not exceed about 300 feet per minute. The velocity between the inlet windows and the fan or heater should not exceed about 800 feet.

The air ducts and flues are usually made of galvanized iron, the ducts being run at the basement ceiling. No. 20 and 22 iron is used for the larger sizes and 24 to 28 for the smaller.

Regulating dampers should be placed in the branches leading to each flue for increasing or reducing the air supply to the different rooms. Adjustable deflectors are often placed at the fork of a pipe for the same purpose. One of these is shown in Fig. 19.

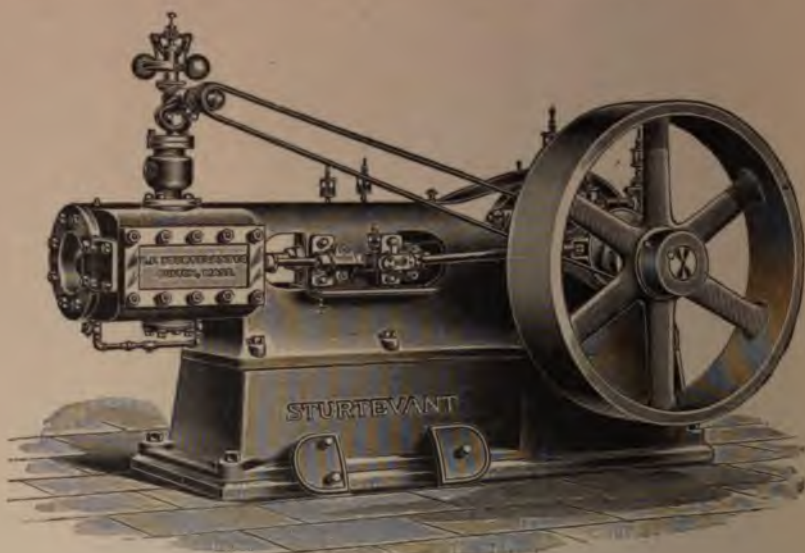


Fig. 17.

Factory Heating. The application of forced blast for the warming of factories and shops is shown in Figs. 20 and 21. The proportional heating surface in this case is generally expressed in the number of cubic feet in the building for each linear foot of 1-inch steam pipe in the heater. On this basis, in factory practice with all of the air taken from out of doors, there are generally allowed from 100 to 150 cubic feet of space per foot of pipe according as exhaust or live steam is used; live steam in this case indicating steam of about 80 pounds pressure. If practically all of the air is returned from the buildings to the heater, these figures may be raised to about 140, as a minimum and possibly 200 as a maximum, per foot of pipe. The heaters in table II may be

changed to linear feet of 1 inch pipe by multiplying the numbers in column three (square feet of surface) by three.

Example.—A machine shop 100 feet long by 50 feet wide and 3 stories, each 10 feet high, is to be warmed by forced blast using

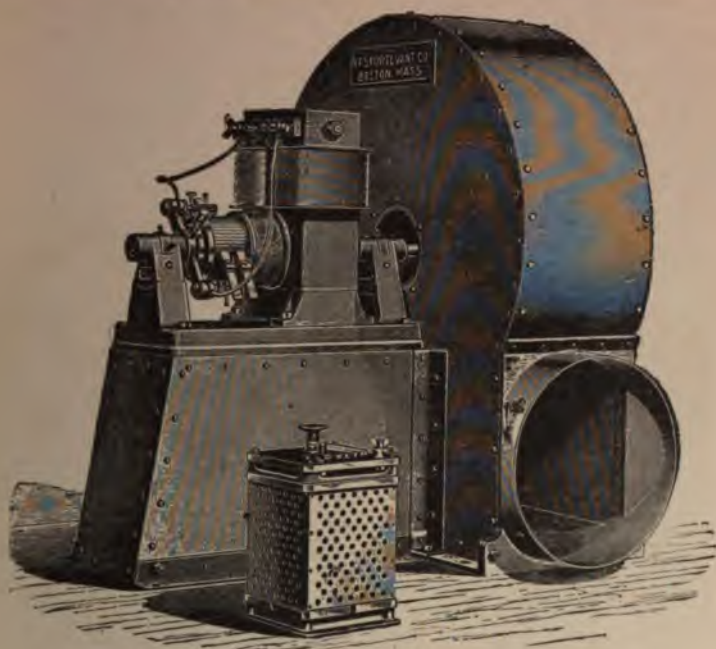


Fig. 18.

exhaust steam in the heater. The air is to be returned to the heater from the building and the whole amount contained in the building is to pass through the heater every 15 minutes. What size of blower will be required and what will be the H.P. of the engine required to run it? How many linear feet of 1-inch pipe should the heater contain?

The total volume of air is

$$100 \times 50 \times 3 \times 10 = 150,000 \text{ cubic feet.}$$

This will require

$$\frac{150,000}{140} = 1071 \text{ feet of pipe.}$$

There are 10,000 cubic feet of air required per minute; hence

from Table III we must use a 4 H.P. engine and a 90-inch blower.

If live steam were used, and the air changed every 20 minutes, we should need $150,000 \div 200 = 750$ feet of pipe, and 7500 cubic feet of air per minute, requiring a $2\frac{1}{2}$ H.P. engine and an 80-inch blower.

In using this method of computation judgment must be used which can only come from experience. The figures given are for average conditions of construction and exposure.

Double Duct System. The varying exposures of the rooms of a school or other building similarly occupied require that more heat shall be supplied to some than to others. Rooms that are on the south side of the building and exposed to the sun may perhaps be kept perfectly comfortable with a supply of heat that will maintain a temperature of only 50 or 60 degrees in rooms on the opposite side of the building which are exposed to high winds and shut off from the warmth of the sun.

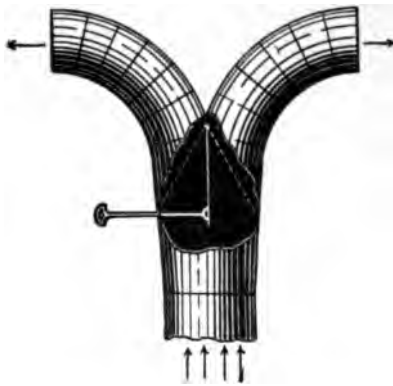


Fig. 19.

With a constant and equal air supply to each room it is evident that the temperature must be directly proportional to the cooling surfaces and exposure, and that no building of this character can be properly heated and ventilated if the temperature cannot be varied without affecting the air supply.

There are two methods of overcoming this difficulty:

The older arrangement consists in heating the air by means of a primary coil at or near the fan to about 60 degrees, or to the minimum temperature required within the building. From the coil it passes to the bases of the various flues and is there still further heated as required, by secondary or supplementary heaters placed at the base of each flue.

With the second and more recent method a single heater is employed and all of the air is heated to the maximum required to maintain the desired temperature in the most exposed rooms, while the temperature of the other rooms is regulated by mixing

with the hot air a sufficient volume of cold air at the bases of the different flues. This result is best accomplished by designing a hot blast apparatus so that the air shall be forced, rather than



Fig. 20.

drawn through the heater, and by providing a by-pass through which it may be discharged without passing across the heated pipes. The passage for the cold air is usually made above and

separate from the heater pipes (see Fig. 19, Part I.). Extending from the apparatus is a double system of ducts, usually of galvanized iron, and suspended from the ceiling. At the base of each flue is placed a mixing damper which is controlled by a chain from the room above and so designed as to admit either a full volume of hot air, a full volume of cold air or to mix them in any



Fig. 21.

desired proportion without affecting the resulting total volume delivered to the room. A damper of this form is shown in Fig. 22.

Fig. 23 shows an arrangement of disc fan and heater where the air is first drawn through a tempering coil, then a portion of it forced through a second heater and into the warm-air pipes while the remainder is by-passed under the heater into the cold-air

pipes. Mixing dampers are placed at the bases of the flues as already described.

EXHAUST VENTILATION.

When air is to be moved against a very slight resistance, as in the case of exhaust ventilation, the disc or propeller type of wheel may be used. This is shown in different forms in Figs. 24, 25 and 26. This type of fan is light in construction, requires but little power at low speeds, and is easily erected. It may be conveniently placed in the attic or upper story of a building, where it may be driven either by a direct or belt-connected electric motor. Fig. 24 shows a fan equipped with a direct-connected motor, and Fig. 27 the general arrangement when a belted motor is used. These fans are largely used for the ventilation of toilet and smoking rooms, restaurants, etc. and are usually mounted in a wall opening, as shown in Fig. 27. A damper should always be provided for shutting off the opening when the fan is not in use.



Fig. 22.

The fans shown in Figs. 25 and 26 are provided with pulleys for belt connection.

Fans of this kind are often connected with the main vent flues of large buildings, such as schools, halls, churches, theatres, etc., and are especially adapted for use in connection with

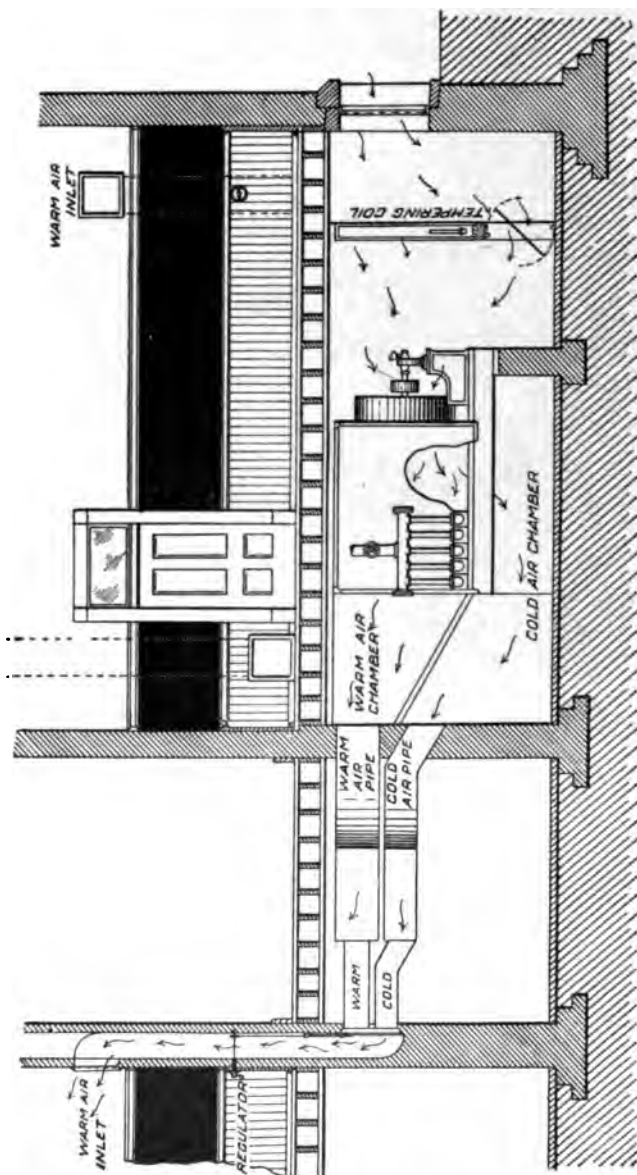


Fig. 23.

gravity heating systems. They are usually run by electric motors, and as a rule are placed in positions where an engine could

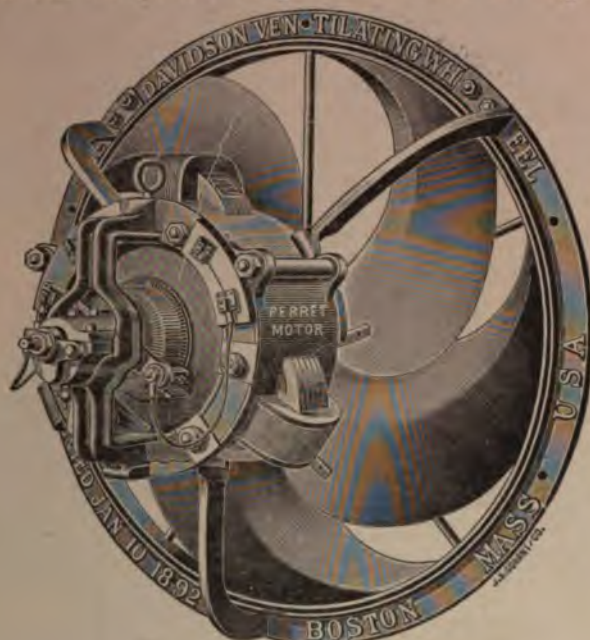


Fig. 24.

not be connected, and also in buildings where steam pressure is not available.

Table IV gives the air delivery per minute against slight resistance, and the proper size of motor for fans of the disc type.

TABLE IV.

Diameter of fan in inches.	Revolutions per minute.	Cubic feet of air delivered per minute.	H. P. of Motor.
12	1,000	600	$\frac{1}{4}$
18	800	1,500	$\frac{1}{2}$
24	500	2,300	1
30	410	3,500	1
36	380	5,700	$1\frac{1}{2}$
42	330	7,800	2
48	280	9,900	3
54	250	12,500	3
60	230	16,000	5

ELECTRIC HEATING.

Unless electricity is produced at a very low cost, it is not commercially practicable for heating residences or large buildings. The electric heater, however, has quite a wide field of application in heating small offices, bathrooms, electric cars, etc. It is a convenient method of warming rooms on cold mornings in late spring and early fall, when furnace or steam heat is not at hand. It has the especial advantage of being instantly available, and



Fig. 25.

the amount of heat can be regulated at will. The heaters are perfectly clean, do not vitiate the air, and are portable.

Electric Heat and Energy. The commercial unit for electricity is one watt for one hour, and is equal to 3.41 B. T. U. Electricity is usually sold on the basis of 1,000 watt hours (called Kilowatt-hours), which is equivalent to 3,410 B. T. U. A watt,

as we have learned, is the product obtained by multiplying a current of 1 ampere by an electro-motive force of 1 volt.

From the above we see that the B. T. U. required per hour for warming, divided by 3,410, will give the Kilowatt-hours necessary for supplying the required amount of heat.

Construction of Electric Heaters. Heat is obtained from the electric current by placing a greater or less resistance in its path. Various forms of heaters have been employed. Some of the simplest consist merely of coils or loops of iron wire, arranged in parallel rows, so that the current can be passed through as many coils as are needed to provide the required amount of heat. In other forms the heating material is surrounded with fire-clay, enamel or asbestos, and in some cases the material itself has been

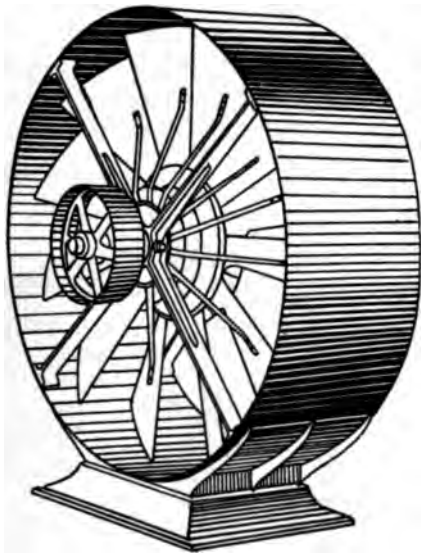


Fig. 26.

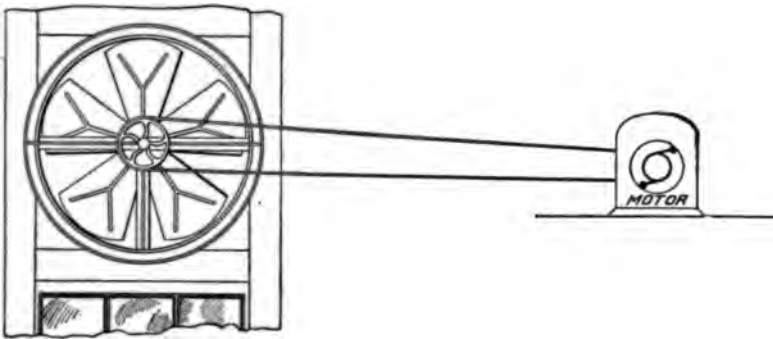


Fig. 27.

such as to give considerable resistance to the current. A form of electric car heater is shown in Fig. 28. Forms of radiators are shown in Figs. 21, 22 and 23, in Part I.

Connections for Electric Heaters. The method of wiring for electric heaters is essentially the same as for lights which require the same amount of current. A constant electro-motive force or voltage is maintained in the main wire leading to the heaters. A much less voltage is carried on the return wire, and the current in passing through the heater from the main to the return, drops in voltage or pressure. This drop provides the energy which is transformed into heat.

The principle of electric heating is much the same as that involved in the non-gravity return system of steam heating. In that system the pressure on the main steam pipes is that of the boiler, while that on the return is much less, the reduction in pressure occurring in the passage of the steam through the



Fig. 28.

radiators; the water of condensation is received into a tank and returned to the boiler by a pump.

In a system of electric heating the main wires must be sufficiently large to prevent a sensible reduction in voltage or pressure between the generator and the heater, so that the pressure in them shall be substantially that in the generator. The pressure or voltage in the main return wire is also constant, but very low, and the generator has an office similar to that of the steam pump in the system just described; that is, of raising the pressure of the return current up to that in the main. The power supplied to the generator can be considered the same as the boiler in the first case. All of the current which passes from the main to the return must flow through the heater and in so doing its pressure or voltage falls from that of the main to that of the return.

From the generator shown in Fig. 29, main and return wires



TYPICAL HEATING INSTALLATION SHOWING SECTIONAL BOILER
AND RADIATOR.
American Radiator Company.

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are run the same as in a two-pipe system of steam heating, and these are proportioned to carry the required current without sensible drop or loss of pressure. Between these wires are placed the various heaters, which are arranged so that when electric connection is made they draw the current from the main and discharge it into the return wire. Connections are made and broken by switches which take the place of valves on steam radiators.

Cost of Electric Heating. The expense of electric heating must in every case be great, unless the electricity can be supplied

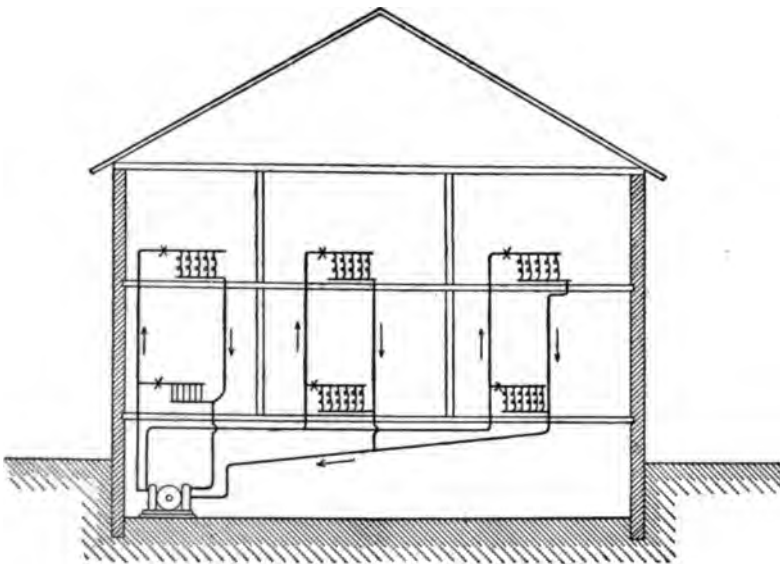


Fig. 29.

at an exceedingly low cost. Estimated on the basis of present practice, the average transformation into electricity does not account for more than 4 per cent of the energy in the fuel which is burned in the furnace: although under best conditions 15 per cent has been realized, it would not be safe to assume that in ordinary practice more than 5 per cent could be transformed into electrical energy. In heating with steam, hot water or hot air, the average amount utilized will probably be about 60 per cent,

so that the expense of electrical heating is approximately from 12 to 15 times greater than by these methods.

TEMPERATURE REGULATORS.

The principal systems of automatic temperature contro^l



Fig. 30.



Fig. 31.

now in use consist of three essential features: First, an air compressor, reservoir and distributing pipes; second, thermostats, which are placed in the rooms to be regulated; and third, special diaphragm or pneumatic valves at the radiators.

The *air compressor* is usually operated by water pressure in

small plants and by steam in larger ones; electricity is used in some cases. Fig. 30 shows a form of water compressor. It is similar in principle to a direct-acting steam pump, in which water under pressure takes the place of steam. A piston in the upper cylinder compresses the air, which is stored in a reservoir provided for the purpose. When the pressure in the reservoir drops below a certain point, the compressor is started automatically, and continues to operate until the pressure is brought up to its working standard.

A *thermostat* is simply a mechanism for opening and closing one or more small valves, and is actuated by changes in the temperature of the air in which it is placed. Fig. 31 shows a thermostat in which the valves are operated by the expansion and contraction of the metal strip E. The degree of temperature at which it acts may be adjusted by throwing the pointer at the bottom one way or the other. Fig. 32 shows the same thermostat with its ornamental casing in place. The thermostat shown in Fig. 33 operates on a somewhat different principle. It consists of a vessel separated into two chambers by a metal diaphragm. One of these chambers is partially filled with a liquid, which will boil at a temperature below that desired in the room. The vapor of the liquid produces considerable pressure at the normal temperature



Fig. 32.

of the room, and a slight increase of heat crowds the diaphragm over and operates the small valves in a manner similar to that of the metal strip in the case just described.

The general form of a *diaphragm valve* is shown in Fig. 34. These replace the usual hand valves at the radiator. They are similar in construction to the ordinary globe or angle valve, except the stem slides up and down instead of being threaded and running in a nut. The top of the stem connects with a flat plate, which rests against a rubber diaphragm. The valve is held open by a spring, as shown, and is closed by admitting compressed air to the space above the diaphragm.

In connecting up the system, small concealed pipes are carried



Fig. 33.

from the air reservoir to the thermostat, which is placed upon an inside wall of the room, and from there to the diaphragm valve at the radiator. When the temperature of the room reaches the maximum point for which the thermostat is set, its action opens a small valve and admits air pressure to the diaphragm, thus closing off the steam from the radiator. When the temperature falls, the thermostat acts in the opposite manner, and shuts off the air pressure from the diaphragm valve, and at the same time opens a small exhaust which allows the air above the diaphragm to escape. The pressure being removed the valve opens and again admits steam to the radiator. Thermostats and diaphragms are also used for operating mixing dampers in a similar manner.

HEATING AND VENTILATION.

Various Classes of Buildings.

The different methods used in heating and ventilation, together with the manner of computing the various proportions of the apparatus, having been taken up, the application of these systems to the different classes of buildings will now be considered briefly.

School Buildings. For school buildings of small size, the furnace system is simple, convenient and generally effective. Its use is confined as a general rule to buildings having not more

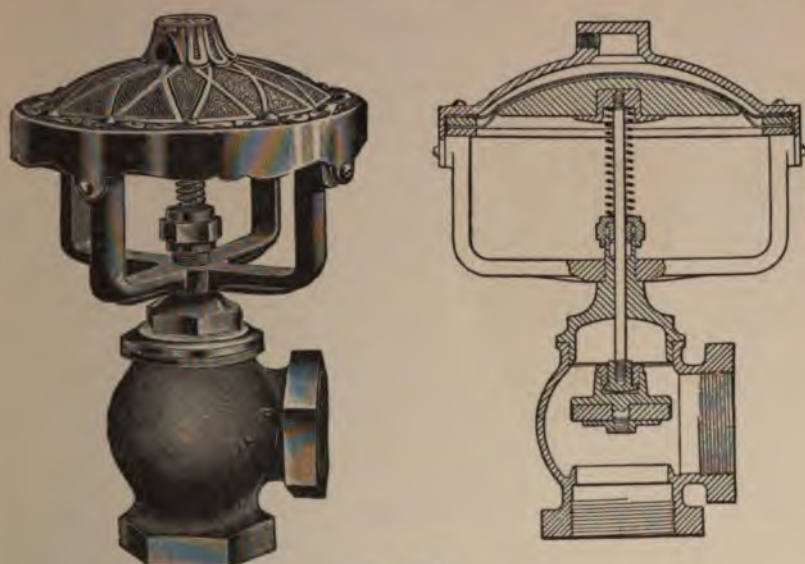


Fig. 34.

than eight rooms. For large ones this method must generally give way to some form of indirect steam system with one or more boilers, which occupy less space, and are more easily cared for than a number of furnaces scattered about in different parts of the basement. Like all systems that depend on natural circulation, the supply and removal of air is considerably affected by changes in the outside temperature and by winds.

The furnaces used are generally built of cast iron; this material being durable, and easily made to present large and

leakage by covering the surfaces or flanges against which they close with some form of asbestos felting. Both inlet and outlet gratings should be provided with adjustable dampers. One of the disadvantages of this system is the delivery of all the heat to the room from a single point, and this not always in a position to give the best results. The outer walls are thus left unwarmed, except as the heat is diffused throughout the room by air currents. When there is considerable glass surface, as in most of our modern schoolrooms, draughts and currents of cold air are frequently found along the outside walls.

A very satisfactory arrangement is the use of indirect heaters for warming the air needed for ventilation, and the placing of direct radiation in the rooms for heating purposes. The general construction of the indirect stacks and flues may be the same, but the heating surface can be reduced, as the air in this case must be raised only to 70 or 75 degrees in zero weather; the heat to offset that lost by conduction, etc., through walls and windows being provided by the direct surface. The mixing dampers are also omitted, and the temperature of the room is regulated by opening or closing the steam valves on the direct coils, which may be done either by hand or automatically. The direct-heating surface, which is best made up of lines of 1½-inch pipe, should be placed along the outer walls beneath the windows. This supplies heat where most needed, and does away with the tendency to draughts. In mild weather, during the spring and fall, the indirect heaters may prove sufficient for both ventilation and warming.

Where direct radiation is placed in the rooms, the quantity of heat supplied is not affected by varying wind conditions, as is the case in indirect heating. Although the air supply may be reduced at times, the heat quantity is not changed. Direct radiation has the disadvantage of a more or less unsightly appearance, and architects and owners often object to the running of mains or risers through the rooms of the building. Air valves should always be provided with drip connections carried to a sink or dry well in the basement.

When circulation coils are used, a good method of drainage is to carry separate returns from each coil to the basement, and place

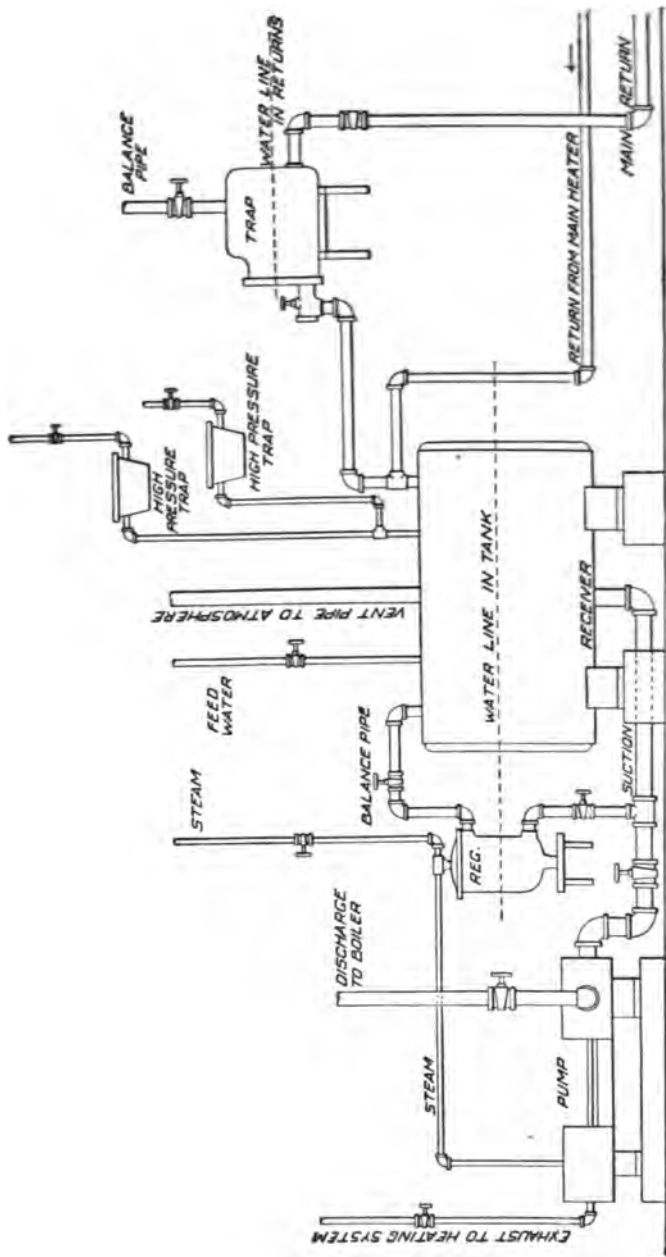


Fig. 85.

the air valves in the drops just below the basement ceiling. A check valve should be placed below the water line in each return.

The fan or blower system for ventilation with direct radiation in the rooms for warming, is considered to be one of the best possible arrangements.

In designing a plant of this kind the main heating coil should be of sufficient size to warm the total air supply to 70 or 75 degrees in the coldest weather, and the direct surface should be proportioned for heating the building independently of the indirect system. Automatic temperature regulation should be used in connection with systems of this kind by placing pneumatic valves on the direct radiation. It is customary to carry from 3 to 8 pounds pressure on the direct system and from 8 to 15 on the main coil depending upon the outside temperature. The foot-warmers, vestibule and office heaters should be placed on a separate line of piping, with separate returns and trap, so that they can be used independently of the rest of the building if desired. Where there is a large assembly hall it should be arranged so that it may be both warmed and ventilated when the rest of the building is shut off. This may be done by a proper arrangement of valves and dampers. When different parts of the system are run on different pressures the returns from each should discharge through separate traps into a receiver having connection with the atmosphere by means of a vent pipe. Fig. 35 shows a common arrangement for the return connections in a combination system of this kind. The different traps discharge into the vented receiver as shown, and the water is pumped back to the boiler automatically when it rises above a given level in the receiver, a pump governor being used to start and stop the pumps as required.

A water level or seal of suitable height is maintained in the main returns by placing the trap at the required elevation and bringing the returns into it near the bottom; a balance pipe is connected with the top for equalizing the pressure the same as in the case of a pump governor. Sometimes a fan is used with the heating coils placed at the base of the flues, instead of in the rooms. Where this is done the radiating surface may be reduced about one-half. This system is less expensive to install, but has the disadvantage

of removing the heating surface from the cold walls where it is most needed.

Churches. Churches may be warmed by furnaces, indirect steam, or by means of a fan. For small buildings the furnace is more commonly used. This apparatus is the simplest of all and is comparatively inexpensive. Heat may be generated quickly, and when the fires are no longer needed they may be allowed to go out without danger of damage to any part of the system from freezing.

It is not usually necessary that the heating apparatus be large enough to warm the entire building at one time to 70 degrees with frequent change of air. If the building is thoroughly warmed before occupancy, either by rotation or by a slow inward movement of outside air, the chapel or Sunday-school room may be shut off until near the close of the service in the auditorium, when a portion of the warm air may be turned into it. When the service ends, the switch damper is opened wide, and all of the air is discharged into the Sunday-school room. The position of the warm-air registers will depend somewhat upon the construction of the building, but it is well to keep them near the outer walls and the colder parts of the room. Large inlet registers should be placed in the floor near the entrance doors, to stop cold drafts from blowing up the aisles when the doors are opened, and also to be used as foot-warmers.

Ceiling ventilators are generally provided, but should be no larger than is necessary to remove the products of combustion from the gaslights, etc. If too large, much of the warmest and purest air will escape through them. The main vent flues should be placed in or near the floor and should be connected with a vent shaft leading outbound. This flue should be provided with a small stove or flue heater made especially for this purpose. In cold weather the natural draft will be found sufficient in most cases. The same general rules follow in the case of indirect steam as have been described for furnace heating. The stacks are placed beneath the registers or flues and mixing dampers provided. If there are large windows, flues should be arranged to open in the window sills so that a sheet of warm air may be delivered in front of the windows, to counteract the effects of cold down drafts from

the exposed glass. These flues may usually be made 3 or 4 inches in depth, and should extend the entire width of the window. Small rooms, such as vestibules, library, pastor's room, etc., are usually heated with direct radiators. Rooms which are used during the week are often connected with an independent heater so that they may be warmed without running the large boilers, as would otherwise be necessary.

When a fan is used it is desirable, if possible, to deliver the air to the auditorium through a large number of small openings. This is often done by constructing a shallow box under each pew, running its entire length, and connecting it with the distributing ducts by means of a pipe from below. The air is delivered at a low velocity through a long slot, as shown in Fig. 36.

The warm-air flues in the window sills should be retained but may be made shallower and the air forced in at a high velocity.

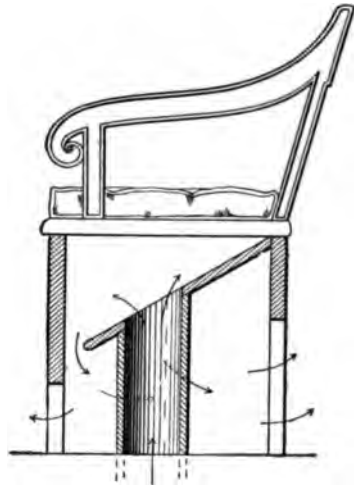


Fig. 36.

Halls. The treatment of a large audience hall is similar to that of a church, and is usually warmed in one of the three ways already described. Where a fan is used the air is commonly delivered through wall registers placed in part near the floor and partly at a height of 7 or 8 feet above it. They should be made of ample size, so that there will be freedom from draughts. A part of the vents should be placed in the ceiling and the remainder near the floor. All ceiling vents both in halls and churches should be provided with dampers, having means for holding them in any desired position. If indirect gravity heaters are used, it will generally be necessary to place heating coils in the vent flues for use in mild weather; but if the fresh air is supplied by means of a fan there will usually be pressure enough in the room to force the air out without the aid of other means. When the vent air ways

are restricted, or the air is impeded in any way, electric ventilating fans are often used. These give especially good results in warmer weather, when natural ventilation is sluggish. The temperature may be regulated either by using the double duct system or by shutting off or turning on a greater or less number of sections in the main heater. After an audience hall is once warmed and filled with people, very little heat is required to keep it comfortable, even in the coldest weather.

Theaters. In designing heating and ventilating systems for theaters, a wide experience and the greatest care are necessary to secure the best results. A theater consists of three parts: the body of the house, or auditorium; the stage and dressing-rooms; and the foyer, lobbies, corridors, stairways and offices. Theaters are usually located in cities, and surrounded with other buildings on two or more sides, thus allowing no direct connection by windows with the external air; for this reason artificial means are necessary for providing suitable ventilation, and a forced circulation by means of a fan is the only satisfactory means of accomplishing this. It is usually advisable to create a slight excess of pressure in the auditorium, in order that all openings shall allow for the discharge rather than the inward leakage of air.

The general and most approved method of air distribution is to force it into closed spaces beneath the auditorium and balcony floors, and allow it to discharge upward through small openings among the seats. One of the best methods is through chair-legs of special latticed design, which are placed over suitable openings in the floor; in this way the air is delivered to the room in small streams at a low velocity without drafts or currents. The discharge ventilation should be largely through ceiling vents, and this may be assisted if necessary by the use of ventilating fans. Vent openings should also be provided at the rear of the balconies either in the wall or ceiling, and these should be connected with an exhaust fan either in the basement or attic, as is most convenient.

The close seating of the occupants produces a large amount of animal heat, which usually increases the temperature from 6 to 10 degrees, or even more; so that in considering a theater once

filled and thoroughly warmed it becomes more of a question of cooling than one of warming to produce comfort.

Office Buildings. This class of buildings may be satisfactorily warmed by direct steam, hot water, or where ventilation is desired by the fan system. Probably direct steam is used more frequently than any other system for this purpose. Vacuum systems are well adapted to the conditions usually found in this type of building, as most modern office buildings have their own light and power plants, and the exhaust steam can be thus utilized for heating purposes. The piping may be either single or double. If the former is used it is better to carry a single main riser to the upper story and run drops to the basement, as by this means the flow of steam and water are in the same direction and much smaller pipes can be used than would be the case if risers were carried from the basement upward. Special provision must be made for the expansion of the risers or drops in tall buildings. They are usually anchored at the center and allowed to expand in both directions. The connections with the radiators must not be so rigid as to cause undue strains or lift the radiators from the floor.

It is customary in most cases to make the connections with the end farthest from the riser; this gives a length of horizontal pipe which has a certain amount of spring, and will care for any vertical movement of the riser which is likely to occur. Forced hot-water circulation is often used in connection with exhaust steam. The water is warmed by the steam in large heaters, similar to feed-water heaters, and circulated through the system by means of centrifugal pumps. This has the usual advantage of hot water over steam, inasmuch as the temperature of the radiators may be regulated to suit the conditions of outside temperature.

Apartment Houses. These are warmed by furnaces, direct steam and hot water. Furnaces are more often used in the smaller houses, as they are cheaper to install, and require a less skilful attendant to operate them. Steam is probably used more than any other system in blocks of larger size. A well-designed single pipe connection with automatic air valves dripped to the basement is probably the most satisfactory in this class of work.

People who are more or less unfamiliar with steam systems are apt to overlook one of the valves in shutting off or turning on steam, and where only one valve is used, the difficulty arising from

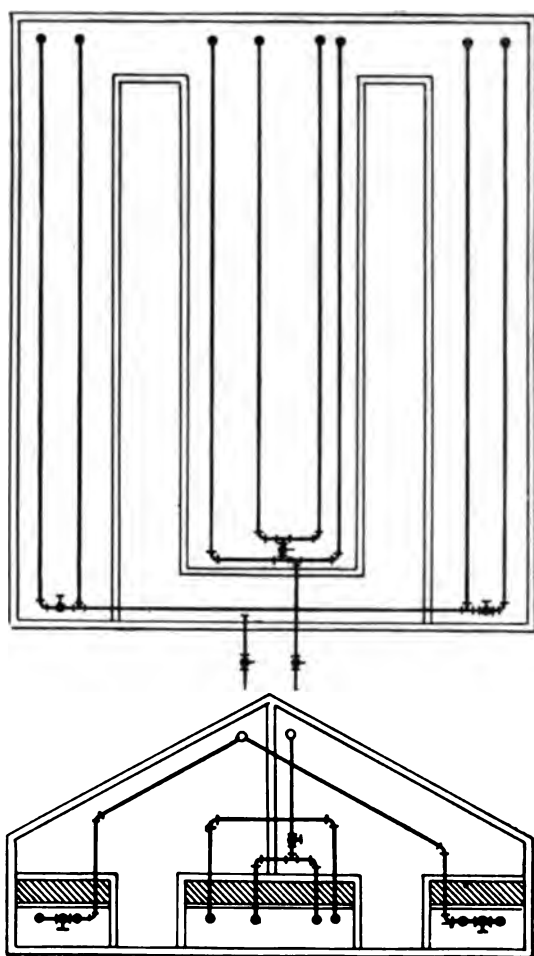


Fig. 37.

this is avoided. Where pet-cock air valves are used they are often left open through carelessness, and the automatic valves, unless dripped, are likely to give more or less trouble.

Greenhouses and conservatories are heated in some cases by

steam and in others by hot water, some florists preferring one and some the other. Either system when properly designed and constructed should give satisfaction, although hot water has its usual advantage of a variable temperature. The methods of piping are in a general way like those already described, and the pipes may be located to run underneath the beds of growing plants or above as bottom or top heat is desired. The main is generally run near the upper part of the greenhouse and to the furthest extremity in one or more branches, with a pitch upward from the heater for hot water and with a pitch downward for steam. The principal

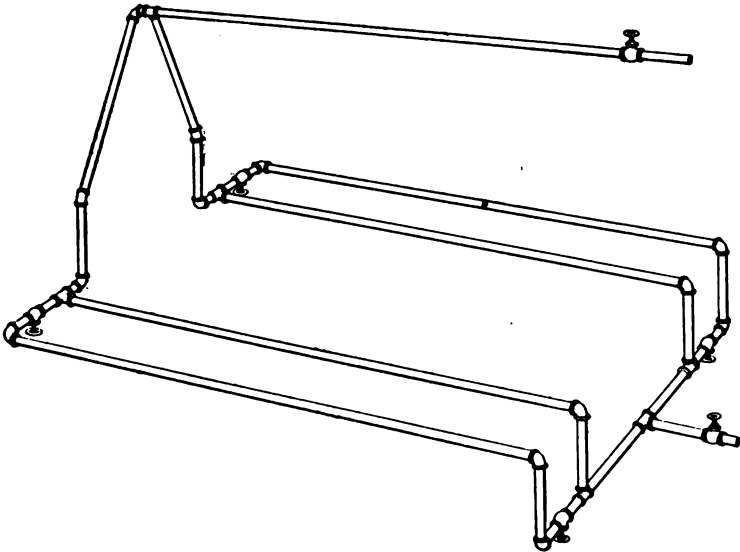


Fig. 38.

radiating surface is made of parallel lines of $1\frac{1}{2}$ inch, or larger, pipe, placed under the benches and supplied by the return current. Figs. 37, 38 and 39 show a common method of running the piping in greenhouse work. Fig. 37 shows a plan and elevation of the building with its lines of pipe, and Figs. 38 and 39 give details of the pipe connections of the outer and inner groups of pipes respectively.

Any system of piping which gives free circulation and which is adapted to the local conditions should give satisfactory results.

The radiating surface may be computed from the rules already given. As the average greenhouse is composed almost entirely of glass we may for purposes of calculation consider it such, and if we divide the total exposed surface by 4 we shall get practically the same result as if we assumed a heat loss of 85 B. T. U. per square foot of surface per hour and an efficiency of 330 B. T. U.

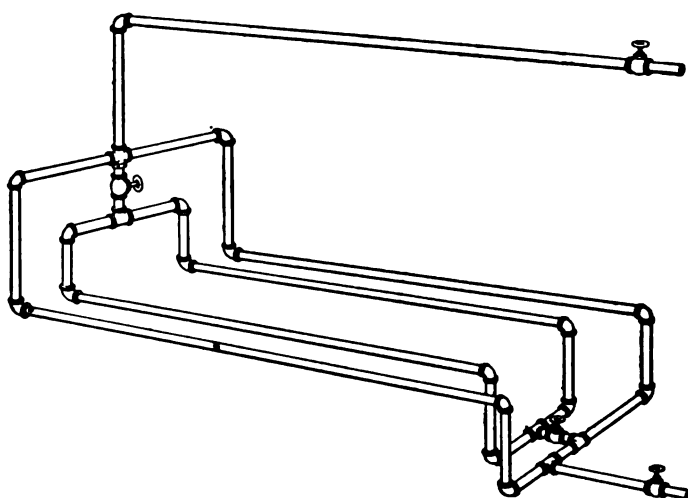


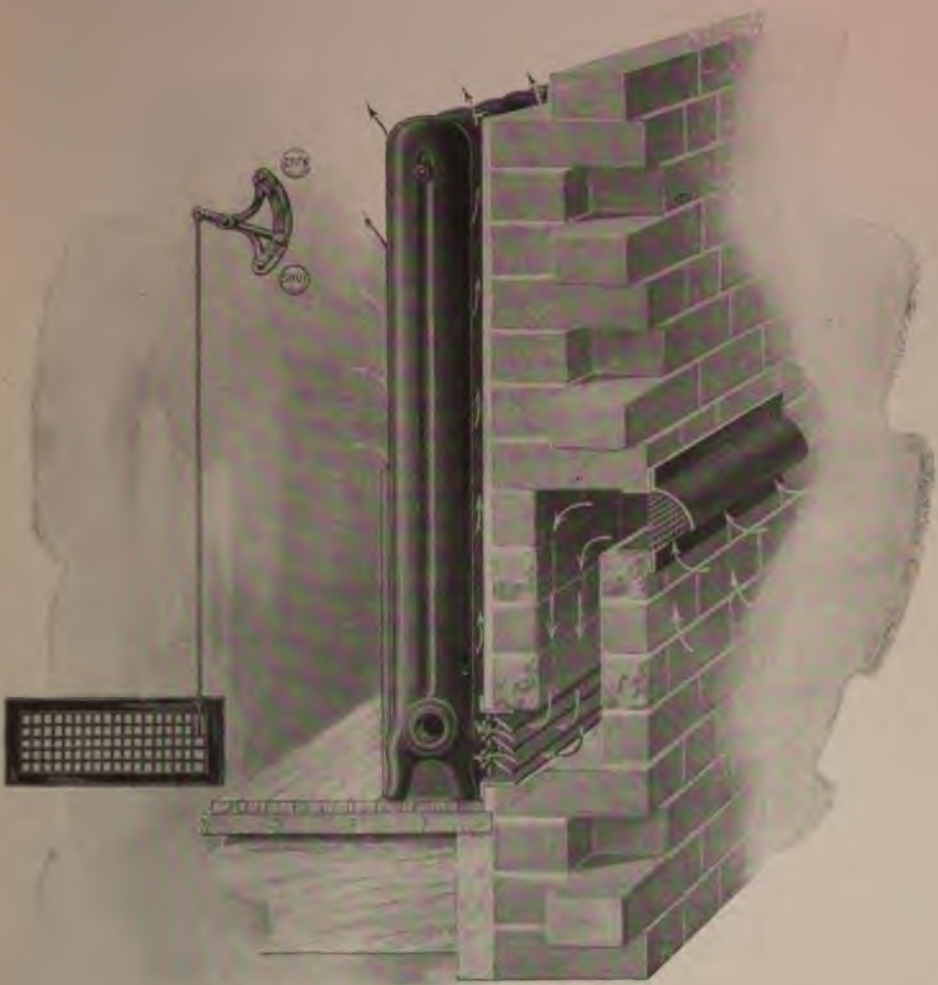
Fig. 30.

for the heating coils; so that we may say in general that the square feet of radiating surface required equals the total exposed surface divided by 4 for steam coils and by 2.5 for hot water. These results should be increased from 10 to 20 per cent for exposed locations.

CARE AND MANAGEMENT.

The care of furnaces, hot-water heaters and steam boilers has been discussed in connection with the design of these different systems of heating, and need not be repeated. The management of the heating and ventilating systems in large school buildings is a matter of much importance, especially in those using a fan system; to obtain the best results as much depends upon the skill of the operating engineer as upon that of the designer.

Beginning in the boiler room, he should exercise special care



DIRECT-INDIRECT SYSTEM OF WARMING, SHOWING ADJUSTABLE DAMPER.
American Radiator Company.



in the management of his fires, and the instruction given in "Boiler Accessories" should be carefully followed; all flues and smoke passages should be kept clear and free from accumulations of soot and ashes by means of a brush or steam jet. Pumps and engine should be kept clean and in perfect adjustment, and extra care should be taken when they are in rooms through which the air supply is drawn, or the odor of oil will be carried to the rooms. All steam traps should be examined at regular intervals to see that they are in working order, and upon any sign of trouble they should be taken apart and carefully cleaned.

The air valves on all direct and indirect radiators should be inspected often, and upon the failure of any room to heat properly the air valve should first be looked to as a probable cause of the difficulty. Adjusting dampers should be placed in the base of each flue, so that the flow to each room may be regulated independently. In starting up a new plant the system should be put in proper balance by a suitable adjustment of these dampers, and when once adjusted they should be marked and left in these positions. The temperature of the rooms should never be regulated by closing the inlet registers. These should never be touched unless the room is to be unused for a day or more.

In designing a fan system provision should be made for "air rotation"; that is, the arrangement should be such that the same air may be taken from the building and passed through the fan and heater continuously. This is usually accomplished by closing the main vent flues and the cold-air inlet to the building, then opening the class-room doors into the corridor ways, and drawing the air down the stairwells to the basement and into the space back of the main heater through doors provided for this purpose. In warming up a building in the morning this should always be practiced until about fifteen minutes before school opens. The vent flues should then be opened, doors into corridors closed, and cold-air inlets opened wide, and the full volume of fresh air taken from out of doors.

At night time the dampers in the main vents should be closed, to prevent the warm air contained in the building from escaping. The fresh air should be delivered to the rooms at a temperature of from 70 to 75 degrees, and this temperature must

be obtained by proper use of the shut-off valves, thus running a greater or less number of sections on the main heater. A little experience will show the engineer how many sections to carry for different degrees of outside temperature. A dial thermometer should be placed in the main warm-air duct near the fan, so that the temperature of the air delivered to the rooms can be easily noted.



Fig. 40.

The exhaust steam from the engine and pumps should be turned into the main heater; this will supply a greater number of sections in mild weather than in cold, owing to the less rapid condensation.

STEAM FITTING.

In order to design a system intelligently the engineer should have some knowledge of the methods of actual construction, the tools used, etc. It is customary where a piece of work is to be done to send a supply of pipe and fittings to the building some-

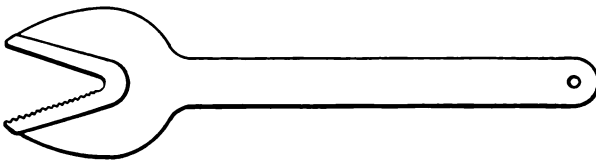


Fig. 41.

what greater than is required, and the workman after receiving the plans of construction, which show the location and sizes of the various pipes to be erected, makes his own measurements, cuts the pipes to the proper length at the building, threads them and screws them into place.

The tools belonging to this trade consist of tongs or wrenches for screwing the pipe together, cutters for cutting, taps and dies for threading the pipe, and vises for holding it in position while cutting or threading. A great variety of tongs and wrenches are

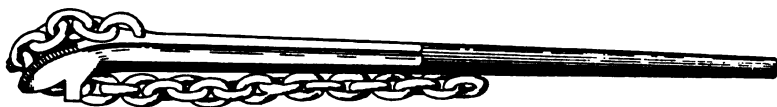


Fig. 42.

to be found on the market. For rapid work no tool is superior to the plain tongs (shown in Fig. 40), especially for the smaller sizes of pipe. The alligator wrench (shown in Fig. 41) is used in a similar manner on light work and where the pipes turn easily.

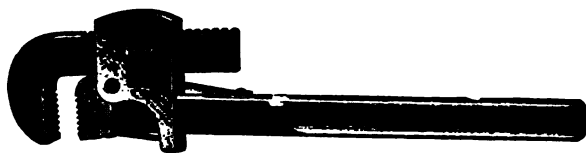


Fig. 43.

For large pipe, chain tongs of some pattern are the best, and may be used with little danger of crushing the pipe. (See Fig. 42.) A form of wrench, known as the Stilson, one form of which is shown in Fig. 43, is widely used. The wrenches or tongs which are used

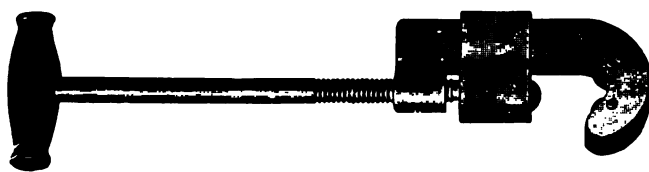


Fig. 44.

for turning the pipe, in most cases, exert more or less lateral pressure, and if too great strength is applied at the handles there is a tendency to split the pipe. The cutter ordinarily employed for small pipe consists of one or more sharp-edged steel wheels,

which are held in an adjustable frame (see Fig. 44); the cutting being performed by applying pressure and revolving it around the pipe. A section of one of the cutting wheels is shown in Fig. 45. With this tool the cutting is accomplished by simply crowding the metal to one side, and hence burrs of considerable size will be formed on the outside and inside of the pipe. Usually the outside burr must be removed by filing before the pipe can be threaded. The inside burr forms a great obstruction



Fig. 45.

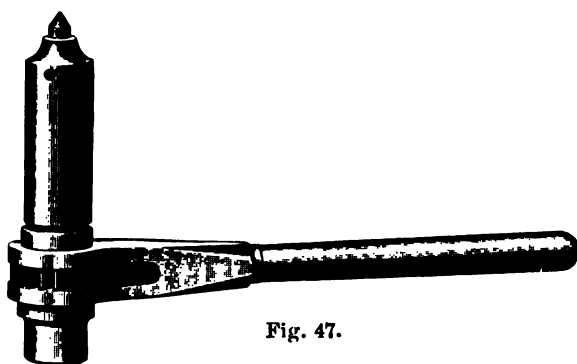


Fig. 47.

to the flow of steam or water, and should in every case be removed by the use of the reamer. There are many forms of reamers for

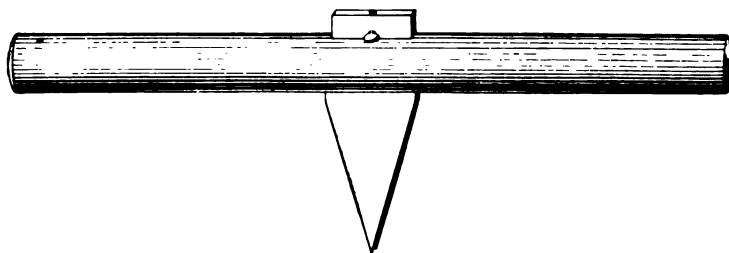


Fig. 46.

use in various cases; one of the simplest is shown in Fig. 46.

The ratchet drill is another tool often used, and is especially useful in drilling holes in pipes or fittings after the work is in

place. One of these is shown in Fig. 47. A common form of vise used for holding the pipe while cutting and threading is shown in Fig. 48. The combination vise is shown in Fig. 49.

The dies for threading the pipes are usually of a solid form, each die fitting into a stock or holder with handles. (See Fig. 50.) The cutting edges of the dies should be kept very sharp and clean, otherwise perfect threads cannot be cut. In cutting threads on wrought iron pipe, oil should always be used, which will tend to prevent heating and crumbling, and make the work easier. In erecting pipe great care should be taken to preserve the proper pitch and alignment, and to appear well the pipes should be screwed together until



Fig. 48.

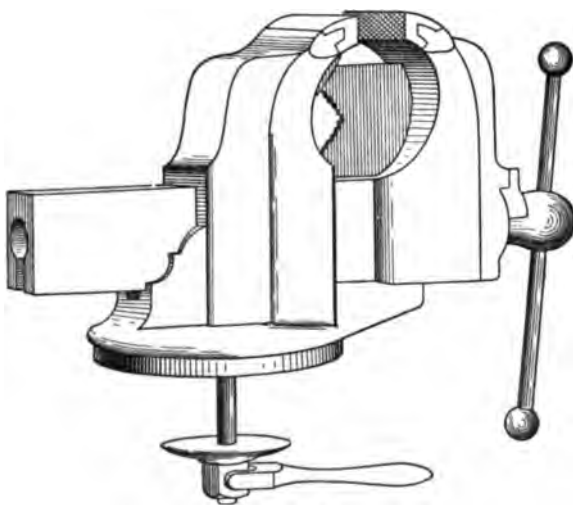


Fig. 49.

no threads are in sight. Every joint should be screwed from 6 to 8 complete turns for sizes 2 inches and under and from 8 to 12 turns for the larger sizes, otherwise there will be danger of leakage.

In screwing pipes together, red or white lead is often used.

It will generally be found that linseed or some good lubricating oil will be equally valuable. If possible, the work should be arranged so that it can be made up with right and left couplings or other fittings.



Fig. 50.

Packed joints, especially unions, are objectionable and likely to leak after use. Flange-unions with copper gaskets should be used on heavy work. Good workmanship in pipe-fitting is shown by the perfection with which small details are executed, and poor workmanship in any of the particulars mentioned may defeat the perfect operation of the best designed plant.



MECHANICAL DRAWING.

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is the method used to show graphically the small details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way to place ideas and calculations on record. Working drawings take the place of lengthy explanations, either written or verbal. A brief inspection of an accurate, well-executed drawing gives a better idea of a machine than a large amount of verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. A thorough training in this important subject is necessary to the success of everyone engaged in mechanical work. The success of a draftsman depends to some extent upon the quality of his instruments and materials. Beginners frequently purchase a cheap grade of instruments. After they have become expert and have learned to take care of their instruments they discard them for those of better construction and finish. This plan has its advantages, but to do the best work, strong, well-made and finely finished instruments are necessary.

INSTRUMENTS AND MATERIALS.

Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manilla paper is frequently used, on account of its toughness and strength, because the drawing is likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong, have uniform thickness and surface, should stretch evenly, and should neither repel nor absorb liquids. It should also allow considerable erasing without spoiling the surface, and it should lie smooth when stretched or when ink or colors are used. It is, of

course, impossible to find all of these qualities in any one paper, as for instance great strength cannot be combined with fine surface.

In selecting a drawing paper the kind should be chosen which combines the greatest number of these qualities for the given work. Of the better class Whatman's are considered by far the best. This paper is made in three grades; the *hot pressed* has a smooth surface and is especially adapted for pencil and very fine line drawing, the *cold pressed* is rougher than the hot pressed, has a finely grained surface and is more suitable for water color drawing; the *rough* is used for tinting. The cold pressed does not take ink as well as the hot pressed, but erasures do not show as much on it, and it is better for general work. There is but little difference in the two sides of Whatman's paper, and either can be used. This paper comes in sheets of standard sizes as follows:—

Cap,	13 × 17 inches.	Elephant,	23 × 28 inches.
Demy,	15 × 20 "	Columbia,	23 × 34 "
Medium,	17 × 22 "	Atlas,	26 × 34 "
Royal,	19 × 24 "	Double Elephant,	27 × 40 "
Super-Royal,	19 × 27 "	Antiquarian,	31 × 53 "
Imperial,	22 × 30 "	Emperor,	48 × 68 "

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. In fastening the paper by this method first fasten the upper left hand corner and then the lower right pulling the paper taut. The other two corners are then fastened, and sufficient number of tacks are placed along the edges to make the paper lie smoothly. For very fine work the paper is usually stretched and glued to the board. To do this the edges of the paper are first turned up all the way round, the margin being at least one inch. The whole surface of the paper included between these turned up edges is then moistened by means of a sponge or soft cloth and paste or glue is spread on the turned up edges. After removing all the surplus water on the paper, the edges are pressed down on the board, commencing at one corner. During this process of laying down the edges, the paper should be stretched slightly by pulling the edges towards the edges of the drawing board. The drawing board is then placed horizontally and left to dry. After the paper has become dry it will be found to be as smooth and tight as a

drum head. If, in stretching, the paper is stretched too much it is likely to split in drying. A slight stretch is sufficient.

Drawing Board. The size of the drawing board depends upon the size of paper. Many draftsmen, however, have several boards of various sizes, as they are very convenient. The drawing board is usually made of soft pine, which should be well seasoned and straight grained. The grain should run lengthwise of the board, and at the two ends there should be pieces about $1\frac{3}{4}$ or 2 inches wide fastened to the board by nails or screws. These end pieces should be perfectly straight for accuracy in using the T-square. Frequently the end pieces are fastened by a glued



DRAWING BOARD.

matched joint, nails and screws being also used. Two cleats on the bottom extending the whole width of the board, will reduce the tendency to warp, and make the board easier to move as they raise it from the table.

Thumb Tacks. Thumb tacks are used for fastening the paper to the drawing board. They are usually made of steel either pressed into shape, as in the cheaper grades, or made with a head of German silver with the point screwed and riveted to it. They are made in various sizes and are very convenient as they can be easily removed from the board. For most work however,

draftsmen use small one-ounce copper or iron tacks, as they can be forced flush with the drawing paper, thus offering no obstruction to the T-square. They also possess the advantage of cheapness.

Pencils. In pencilling a drawing the lines should be very fine and light. To obtain these light lines a hard lead pencil must be used. Lead pencils are graded according to their hardness, and are numbered by using the letter H. In general a lead pencil of 5H (or HHHHH) or 6H should be used. A softer pencil, 4H,

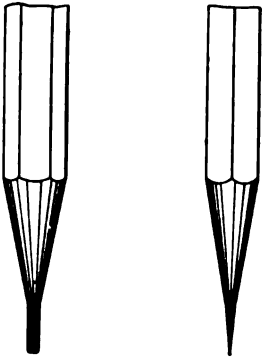


Fig. 1.

is better for making letters, figures and points. A hard lead pencil should be sharpened as shown in Fig. 1. The wood is cut away so that about $\frac{1}{4}$ or $\frac{3}{8}$ inch of lead projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file. It should be ground to a chisel edge and the corners slightly rounded. In making the straight lines the chisel edge should be used by placing it against the T-square or triangle, and because of the chisel edge

the lead will remain sharp much longer than if sharpened to a point. This chisel edge enables the draftsman to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, as the lines will then be somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge in the compasses as well as for the pencil.

In using a very hard lead pencil, the chisel edge will make a deep depression in the paper if much pressure is put on the pencil. As this depression cannot be erased it is much better to press lightly on the pencil.

Erasers. In making drawings, but little erasing should be necessary. However, in case this is necessary, a soft rubber should be used. In erasing a line or letter, great care must be exercised or the surrounding work will also become erased. To prevent this, some draftsmen cut a slit about 3 inches long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide in a card as shown in Fig. 2. The card is then

placed over the work and the line erased without erasing the rest of the drawing. An erasing shield of a form similar to that shown in Fig. 3 is very convenient, especially in erasing letters. It is made of thin sheet metal and is clean and durable.

For cleaning drawings, a sponge rubber may be used. Bread

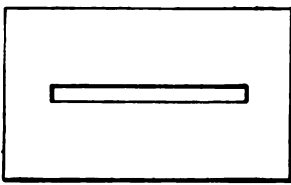


Fig. 2.

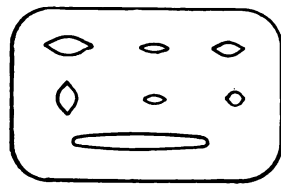


Fig. 3.

crumbs are also used for this purpose. To clean the drawing scatter *dry* bread crumbs over it and rub them on the surface with the hand.

T-Square. The T-square consists of a thin straight edge



Fig. 4.

called the blade, fastened to a head at right angles to it. It gets its name from the general shape. T-squares are made of various materials, wood being the most commonly used. Fig. 4 shows an ordinary form of T-square which is adapted to most work. In Fig. 5 is shown a T-square with edges made of ebony or mahogany, as these woods are much harder than pear wood or maple, which is generally used. The head is formed so as to fit against the left-hand edge of the drawing board, while the blade extends over the surface. It is desirable to have the blade of the T-square form a right angle with the head, so that the lines drawn with the T-square will be at right angles to the left-hand edge of the board. This, however, is not absolutely necessary, because the lines drawn with the T-square are always with reference to one edge of the

board only, and if this edge of the board is straight, the lines drawn with the T-square will be parallel to each other. The T-square should never be used except with the left-hand edge of the board, as it is almost impossible to find a drawing board with the edges parallel or at right angles to each other.

The T-square with an adjustable head is frequently very convenient, as it is sometimes necessary to draw lines parallel to each

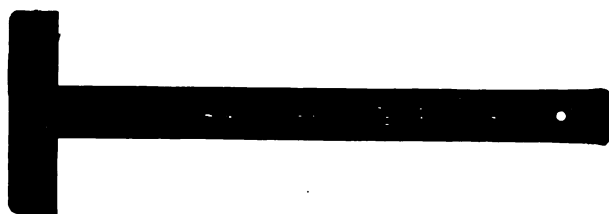


Fig. 5.

other which are not at right angles to the left-hand edge of the board. This form of T-square is similar to the ordinary T-square already described, but the head is swiveled so that it may be clamped at any desired angle. The ordinary T-square as shown

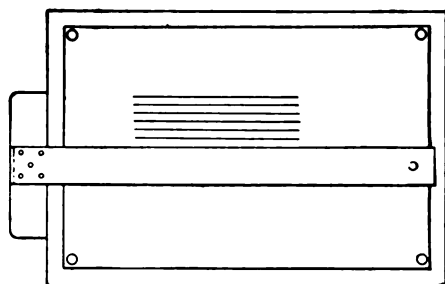


Fig. 6.

in Figs. 4 and 5 is, however, adapted to almost any class of drawing.

Fig. 6 shows the method of drawing parallel horizontal lines with the T-square. With the head of the T-square in contact with the left-hand edge of the board, the lines may be

drawn by moving the T-square to the desired position. In using the T-square the upper edge should always be used for drawing as the two edges may not be exactly parallel and straight, and also it is more convenient to use this edge with the triangles. If it is necessary to use a straight edge for trimming drawings or cutting the paper from the board, the lower edge of the T-square should be used so that the upper edge may not be marred.

For accurate work it is absolutely necessary that the working edge of the T-square should be exactly straight. To test the

straightness of the edge of the T-square, two T-squares may be placed together as shown in Fig. 7. This figure shows plainly that the edge of one of the T-squares is crooked. This fact, however, does not prove that either one is straight, and for this determination a third blade must be used and tried with the two given T-squares successively.

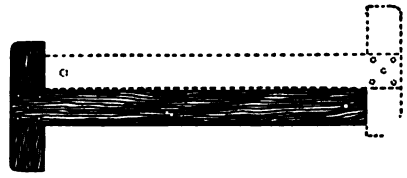
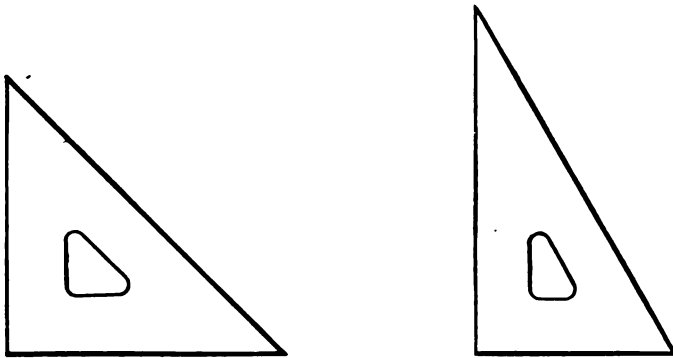


Fig. 7.

Triangles. Triangles are made of various substances such as wood, rubber, celluloid and steel. Wooden triangles are cheap but are likely to warp and get out of shape. The rubber triangles are frequently used, and are in general satisfactory. The transparent celluloid triangle is, however, extensively used on account of its transparency, which enables the draftsmen to see the work already done even when covered with the triangle. In using a rubber or celluloid triangle take care that it lies perfectly flat or



TRIANGLES.

is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles are made in various sizes, and many draftsmen have several constantly on hand. A triangle from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle measuring about 4 inches

on a side will be found useful. Two triangles are necessary for every draftsman, one having two angles of 45 degrees each and one a right angle; and the other having one angle of 60 degrees, one of 30 degrees and one of 90 degrees.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of

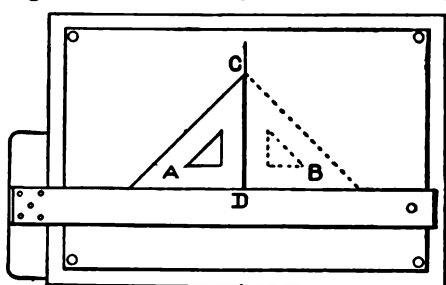


Fig. 8.

the right angle of a triangle, place the triangle with the lower edge resting on the edge of the T-square, as shown in Fig. 8. Now draw the line C D, which should be perpendicular to the edge of the T-square. The same triangle should then

be placed in the position shown at B. If the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle should exactly coincide with the line C D.

To test the accuracy of the 45-degree triangles, first test the right angle then place the triangle with the lower edge resting on the working edge of the T-square, and draw the line E F as shown in Fig. 9. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

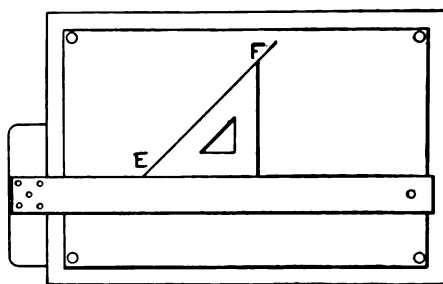


Fig. 9.

Triangles are very convenient in drawing lines at right angles to the T-square. The method of doing this is shown in Fig. 10. Triangles are also used in drawing lines at an angle with the horizontal, by placing them on the board as shown in Fig. 11. Suppose the line E F (Fig. 12) is drawn at any angle, and we wish to draw a line through the point P parallel to it.

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MEDIUM PRICED DRAWING OUTFIT SHOWING THE INSTRUMENTS NECESSARY FOR PURSUING A COURSE IN MECHANICAL DRAWING.

First place one of the triangles as shown at A, having one edge coinciding with the given line. Now take the other triangle and place one of its edges in contact with the bottom edge of triangle A. Holding the triangle B firmly with the left hand the triangle A may be slipped along to the right or to the left until the edge of the triangle reaches the point P. The line M N may then be drawn along the edge of the triangle passing through the point P. In place of the triangle B any straight edge such as a T-square may be used.

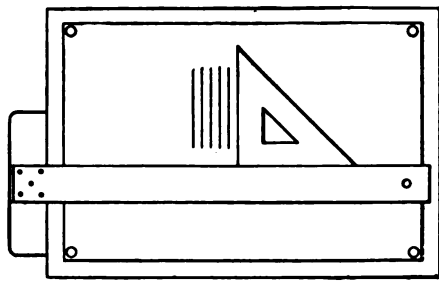


Fig. 10.

A line can be drawn perpendicular to another by means of the triangles as follows. Let E F (Fig. 13) be the given line, and suppose we wish to draw a line perpendicular to E F through the point D. Place the longest side of one of the triangles so that it coincides with the line E F, as the triangle is shown in position at A. Place the other triangle (or any straight edge) in the position of the triangle as shown at B, one edge resting against the edge of the triangle A. Then holding B with the left hand, place the tri-

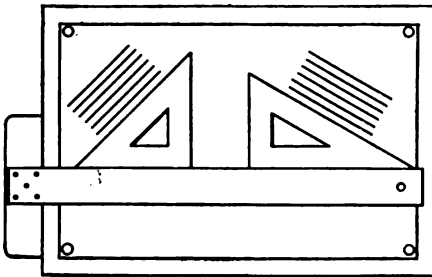


Fig. 11.

angle A in the position shown at C, so that the longest side passes through the point D. A line can then be drawn through the point D perpendicular to E F.

In previous figures we have seen how lines may be drawn making angles of 30, 45, 60 and 90 degrees with the horizontal. If it is desired to draw lines forming angles of 15 and 75 degrees the triangles may be placed as shown in Fig. 14.

In using the triangles and T-square almost any line may be drawn. Suppose we wish to draw a rectangle having one side

horizontal. First place the T-square as shown in Fig. 15. By moving the T-square up or down, the sides A B and D C may be drawn, because they are horizontal and parallel. Now place one of the triangles resting on the T-square as shown at E, and having the left-hand edge passing through the point D. The vertical

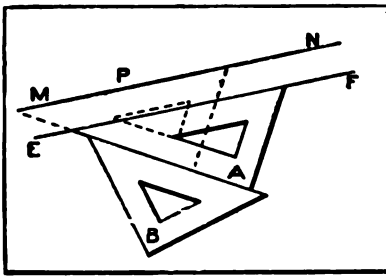


Fig. 12.

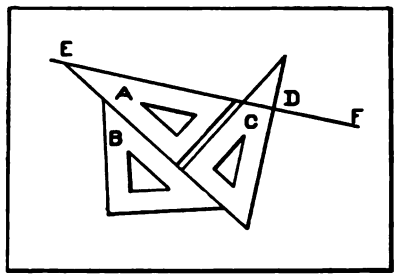


Fig. 13.

line D A may be drawn, and by sliding the triangle along the edge of the T-square to the position F the line B C may be drawn by using the same edge. These positions are shown dotted in Fig. 15.

If the rectangle is to be placed in some other position on the drawing board, as shown in Fig. 16, place the 45-degree triangle

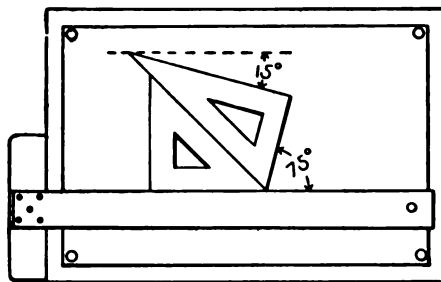


Fig. 14.

F so that one edge is parallel to or coincides with the side D C. Now holding the triangle F in position place the triangle H so that its upper edge coincides with the lower edge of the triangle F. By holding H in position

and sliding the triangle F along its upper edge, the sides A B and D C may be drawn. To draw the sides A D and B C the triangle should be used as shown at E.

Compasses. Compasses are used for drawing circles and arcs of circles. They are made of various materials and in various sizes. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver. It does not soil

readily, it has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the soft metal they do not wear well.

The compasses are made in the form shown in Figs. 17 and 18. Pencil and pen points are provided, as shown in Fig. 17. Either pen or pencil may be inserted in one leg by means of a shank and socket. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point is separate, and is made of a piece of round steel wire having a square shoulder at one or both ends. Below this shoulder the needle point projects. The needle is made in this form so that the hole in the paper may be very minute.

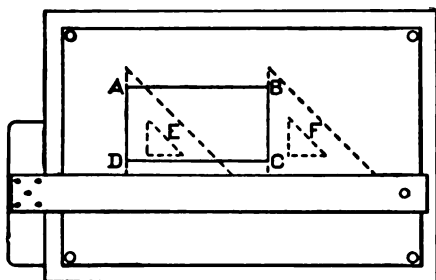


Fig. 15.

In some instruments lock nuts are used to hold the joint firmly in position. These lock nuts are thin discs of steel, with

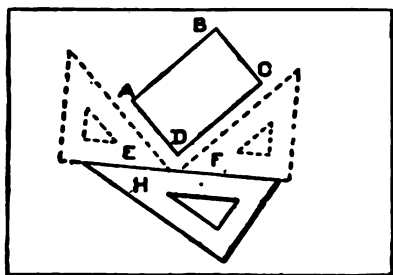


Fig. 16.

notches for using a wrench or forked key. Fig. 19 shows the detail of the joint of high grade instruments. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, and at the same time gives the proper stiffness. The flat surface of one of

the legs is faced with steel, the other being of German silver, in order that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dust and dirt and to prevent rusting of the steel face.

Figs. 20, 21, and 22 show the detail of the socket; in some

instruments the shank and socket are pentagonal, as shown in Fig. 20. The shank enters the socket loosely, and is held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

In Fig. 21 is shown another form of shank. This is round, having a flat top. A set screw is also used to hold this in position. A still better form of socket is shown in Fig. 22; the hole

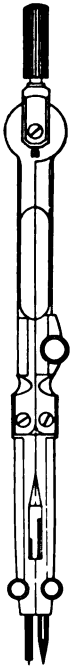


Fig. 17.

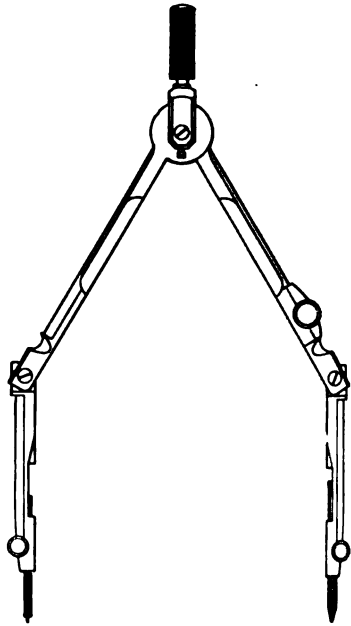
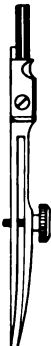


Fig. 18.

is made tapered and is circular. The shank fits accurately, and is held in perfect alignment by a small steel key. The clamping screw is placed upon the side, and keeps the two portions of the split socket together.

Figs. 17 and 18 show that both legs of the compasses are jointed in order that the lower part of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of

the pen will press equally on the paper. In pencilling circles it is not as necessary that the pencil should be kept vertical; it is a good plan, however, to learn to use them in this way both in pencilling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

In removing the pencil or pen, it should be pulled out straight. If bent from side to side the socket will become enlarged and the shank worn; this will render the instrument inaccurate. For drawing large circles the lengthening bar shown in Fig. 17 should be used. When using the lengthening bar the

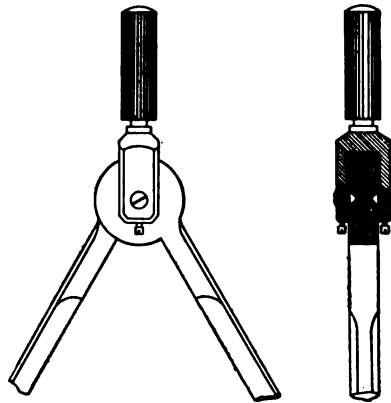


Fig. 19.

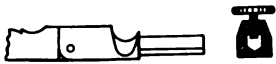


Fig. 20.



Fig. 21.

needle point should be steadied with one hand and the circle described with the other.

Dividers. Dividers, shown in Fig. 23, are made similar to the compasses. They are used for laying off distances on the drawing, either from scales or from other parts of the drawing. They



Fig. 22.

may also be used for dividing a line into equal parts. When dividing a line into equal parts the dividers should be turned in the opposite direction each time, so that the moving point passes alternately to the right and to the left. The instrument can then be operated readily with one hand. The points of the dividers should be very sharp so that the holes made in the paper will be small. If large holes are made in the paper, and the distances between

the points are not exact, accurate spacing cannot be done. Sometimes the compasses are furnished with steel divider points in addition to the pen and pencil points. The compasses may then be used either as dividers or as compasses. Many draftsmen use a *needle point* in place of dividers for making measurements from a scale. The eye end of a needle is first broken off and the needle then forced into a small handle made of a round piece of soft pine. This instrument is very convenient for indicating the intersection of lines and marking off distances.



Fig. 23.

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy to use in making small circles, fillets, etc. The leverage of the long leg is so great that it is very difficult to draw small circles accurately. For this reason the bow compasses shown in Figs. 24 and 25 should be used on all arcs and circles having a radius of less than three-quarters inch. The bow compasses are also convenient for duplicating small circles such as those which represent boiler tubes, bolt holes, etc., since there is no tendency to slip.

The needle point must be adjusted to the same length as the pen or pencil point if very small circles are to be drawn. The adjustment for altering the radius of the circle can be made by turning the nut. If the change in radius is considerable the points should be pressed together to remove the pressure from the nut which can then be turned in either direction with but little wear on the threads.

Fig. 26 shows another bow instrument which is frequently used in small work in place of the dividers. It has the advantage of retaining the adjustment.

Drawing Pen. For drawing straight lines and curves that are not arcs of circles, the line pen (sometimes called the ruling pen) is used. It consists of two blades of steel fastened to a handle as shown in Fig. 27. The distance between the pen points can be adjusted by the thumb screw, thus regulating the width of line to be drawn. The blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

The pen may be filled by means of a common steel pen or with the quill which is provided with some liquid inks. The pen should not be dipped in the ink because it will then be necessary to wipe the outside of the blades before use. The ink should fill the pen to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work the pen should be carefully wiped with

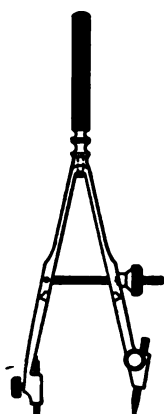


Fig. 24.

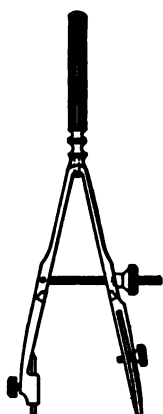


Fig. 25.

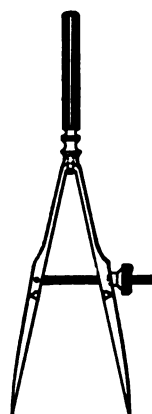


Fig. 26.

chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper. If the points do not bear equally the line will be ragged. If both points touch, and the pen is in good condition the line will be smooth. The pen is usually inclined slightly in the direction in which the line is drawn. The pen



Fig. 27.

should *touch* the triangle or T-square which serve as guides, but it should not be pressed against them because the lines will then be uneven. The points of the pen should be close to the edge of the triangle or T-square, but should not touch it.

To Sharpen the Drawing Pen. After the pen has been used for some time the points become worn, and it is impossible

to make smooth lines. This is especially true if rough paper is used. The pen can be put in proper condition by sharpening it. To do this take a small, flat, close-grained oil-stone. The blades should first be screwed together, and the points of the pen can be given the proper shape by drawing the pen back and forth over the stone changing the inclination so that the shape of the ends will be parabolic. This process dulls the points but gives them the proper shape, and makes them of the same length.

To sharpen the pen, separate the points slightly and rub one of them on the oil-stone. While doing this keep the pen at an angle of from 10 to 15 degrees with the face of the stone, and give it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After the pen point has become fairly sharp the other point should be ground in the same manner. All the grinding should be done on the *outside* of the blades. The burr should be removed from the inside of the blades by using a piece of leather or a piece of pine wood.

Ink should now be placed between the blades and the pen tried. The pen should make a smooth line whether fine or heavy, but if it does not the grinding must be continued and the pen tried frequently.

Ink. India ink is always used for drawing as it makes a permanent black line. It may be purchased in solid stick form or as a liquid. The liquid form is very convenient as much time is saved, and all the lines will be of the same color; the acid in the ink, however, corrodes steel and makes it necessary to keep the pen perfectly clean.

Some draftsmen prefer to use the India ink which comes in stick form. To prepare it for use, a little water should be placed in a saucer and one end of the stick placed in it. The ink is ground by giving it a twisting movement. When the water has become black and slightly thickened, it should be tried. A heavy line should be made on a sheet of paper and allowed to dry. If the line has a grayish appearance, more grinding is necessary. After the ink is thick enough to make a good black line, the grinding should cease, because very thick ink will not flow freely from the pen. If, however, the ink has become too

thick, it may be diluted with water. After using, the stick should be wiped dry to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily if it has once become dry. If the ink is kept covered it will keep for two or three days.

Scales. Scales are used for obtaining the various measurements on drawings. They are made in several forms, the most convenient being the flat with beveled edges and the triangular. The scale is usually a little over 12 inches long and is graduated for a distance of 12 inches. The triangular scale shown in Fig. 28 has six surfaces for graduations, thus allowing many graduations on the same scale.

The graduations on the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two.

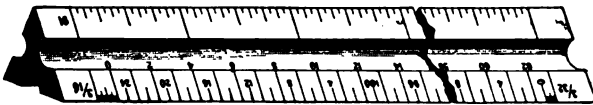


Fig. 28.

Thus we make drawings full size, half size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects, civil engineers, and for measuring on indicator cards.

The scale should never be used for drawing lines in place of triangles or T-square.

Protractor. The protractor is an instrument used for laying off and measuring angles. It is made of steel, brass, horn and paper. If made of metal the central portion is cut out as shown in Fig. 29, so that the draftsman can see the drawing. The outer edge is divided into degrees and tenths of degrees. Sometimes the graduations are very fine. In using a protractor a very sharp hard pencil should be used so that the lines will be fine and accurate.

The protractor should be placed so that the given line (pro-

duced if necessary) coincides with the two O marks. The center of the circle being placed at the point through which the desired line is to be drawn. The division can then be marked with the pencil point or needle point.

Irregular Curve. One of the conveniences of a draftsman's

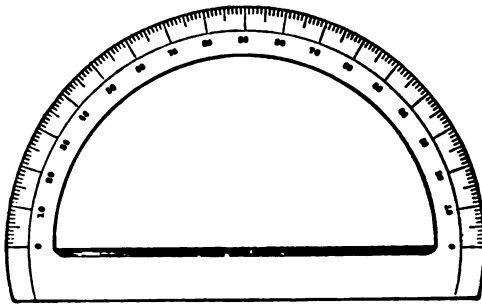


Fig. 29.

outfit is the French or irregular curve. It is made of wood, hard rubber or celluloid, the last named material being the best. It is made in various shapes, two of the most common being

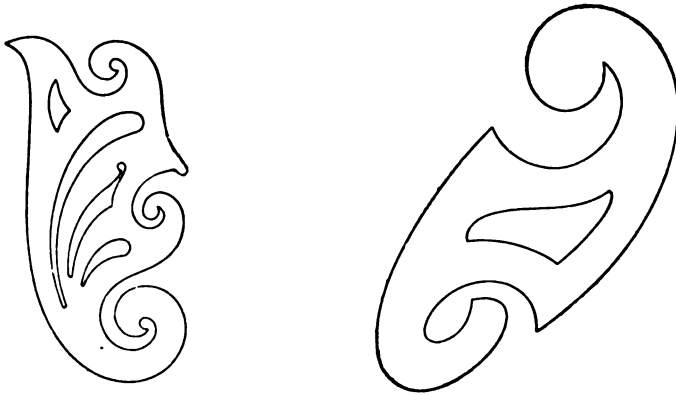


Fig. 30.

shown in Fig. 30. This instrument is used for drawing curves other than arcs of circles, and both pencil and line pen can be used.

To draw the curve, a series of points is first located and then the curve drawn passing through them by using the part of the irregular curve that passes through several of them. The

curve is shifted for this work from one position to another. It frequently facilitates the work and improves its appearance to draw a free hand pencil curve through the points and then use the irregular curve, taking care that it always fits at least *three* points.

In inking the curve, the blades of the pen must be kept

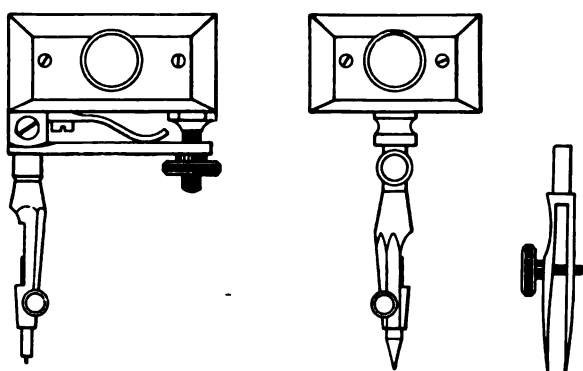


Fig. 31.

tangent to the curve, thus necessitating a continual change of direction.

Beam Compasses. The ordinary compasses are not large enough to draw circles having a diameter greater than about 8 or 10 inches. A convenient instrument for larger circles is found in the beam compasses shown in Fig. 31. The two parts called channels carrying the pen or pencil and the needle point are clamped to a wooden beam; the distance between them being equal to the radius of the circle. Accurate adjustment is obtained by means of a thumb nut underneath one of the channel pieces.

PLATES.

Plates I, II and III are provided to give practice in the use of the drawing instruments. Drawing paper at least 11 inches by 15 inches should be used to allow border lines 10 inches by 14 inches. First, draw carefully in pencil and then ink in. Especial care should be taken as to quality and width of line, intersections, and the joining of curved and straight lines.

These are followed by examples for lettering. Plate IV should be drawn first in pencil and then in ink.



FIG. 1

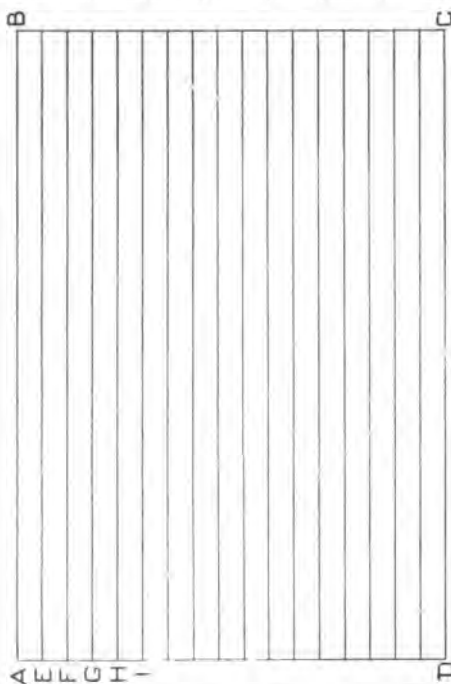
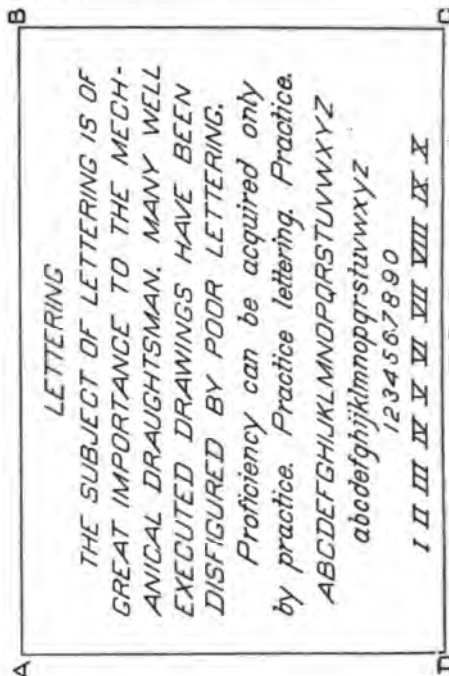


FIG. 2



LETTERING

THE SUBJECT OF LETTERING IS OF
GREAT IMPORTANCE TO THE MECH-
ANICAL DRAUGHTSMAN. MANY WELL
EXECUTED DRAWINGS HAVE BEEN
DISFIGURED BY POOR LETTERING.

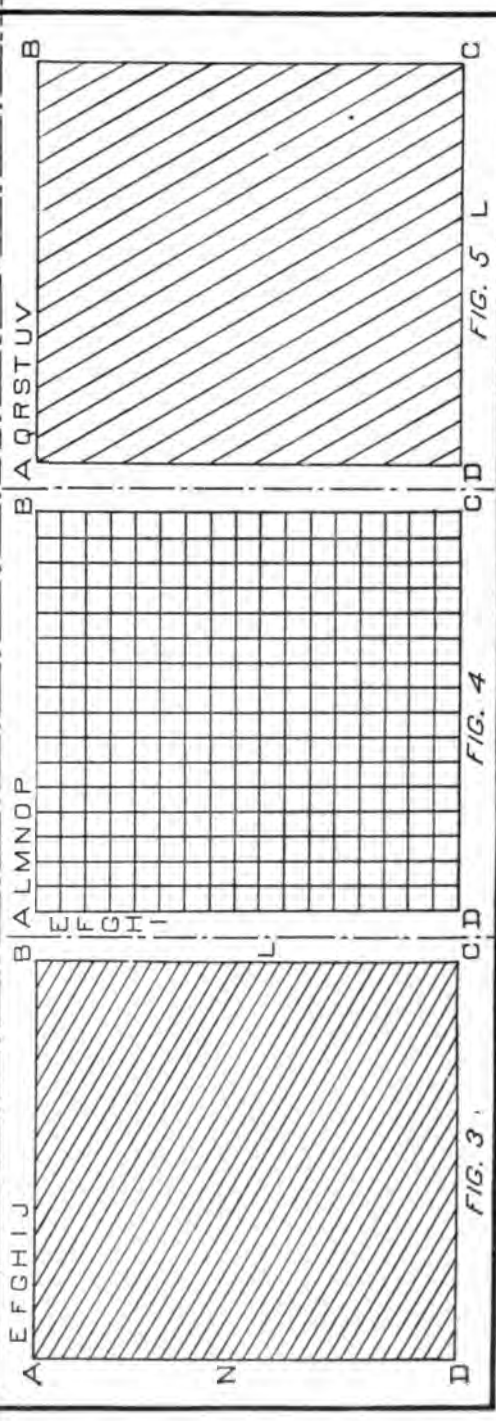
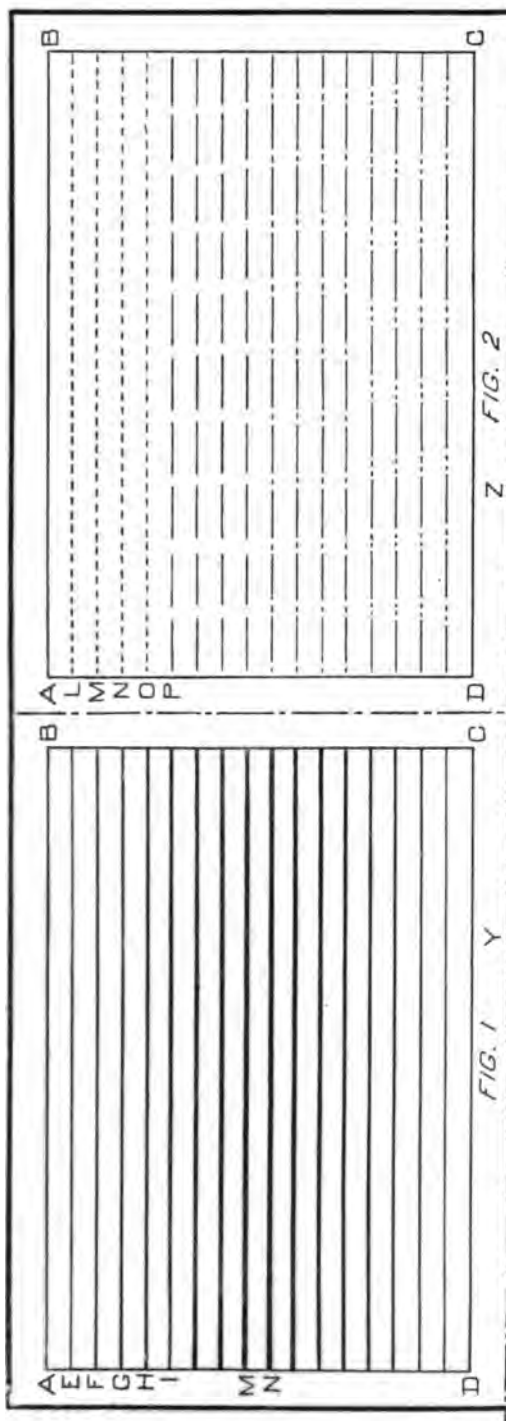
*Proficiency can be acquired only
by practice. Practice lettering. Practice.*

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

1234567890

I II III IV V VI VII VIII IX X



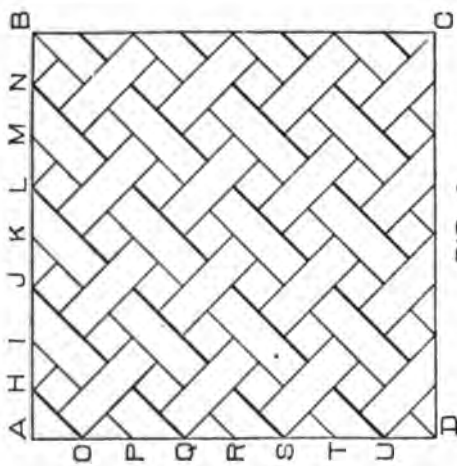


FIG. 3

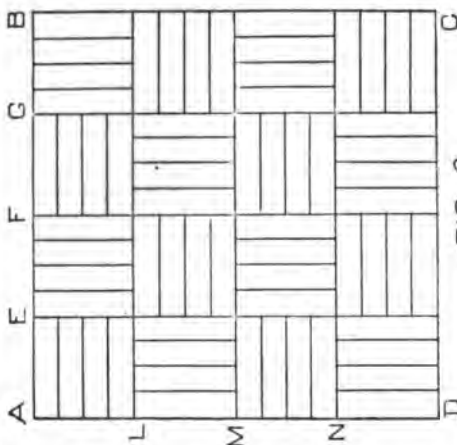


FIG. 2

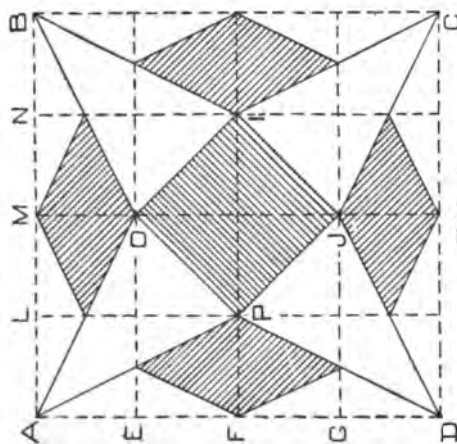


FIG. 1

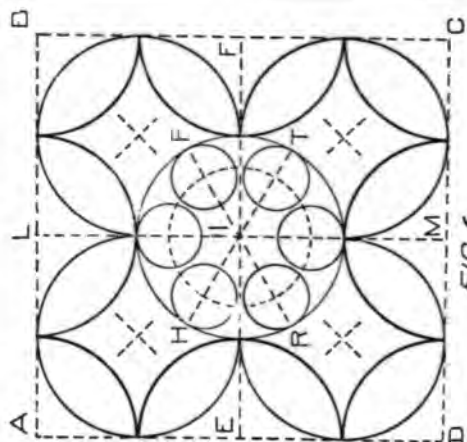


FIG. 6

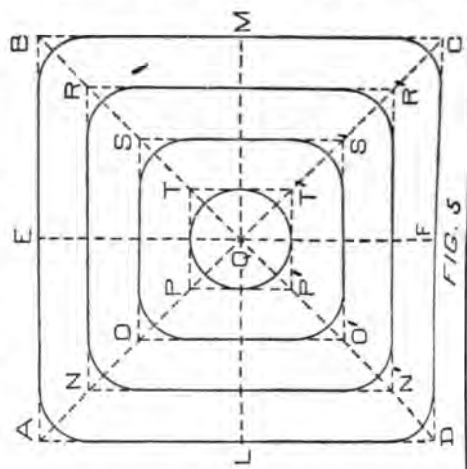


FIG. 5

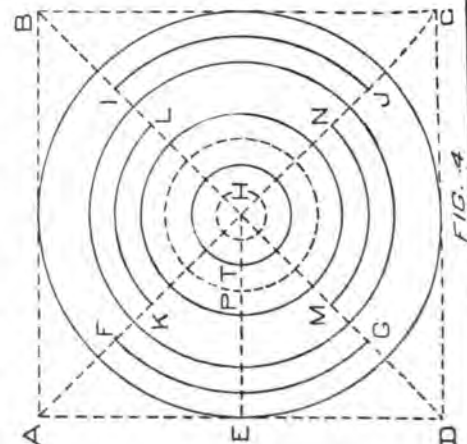


FIG. 4

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IN
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MACHINE DRAWINGS
AND
PROJECTIONS
BOSTON, MASS., U.S.A.
1901

APRIL 24, 1901

HERBERT CHANDLER

CHICAGO, ILL.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Vertical Roman Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Inclined Roman Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Vertical Gothic Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Inclined Gothic Capitals.

A B C D E F G H I J K L M N

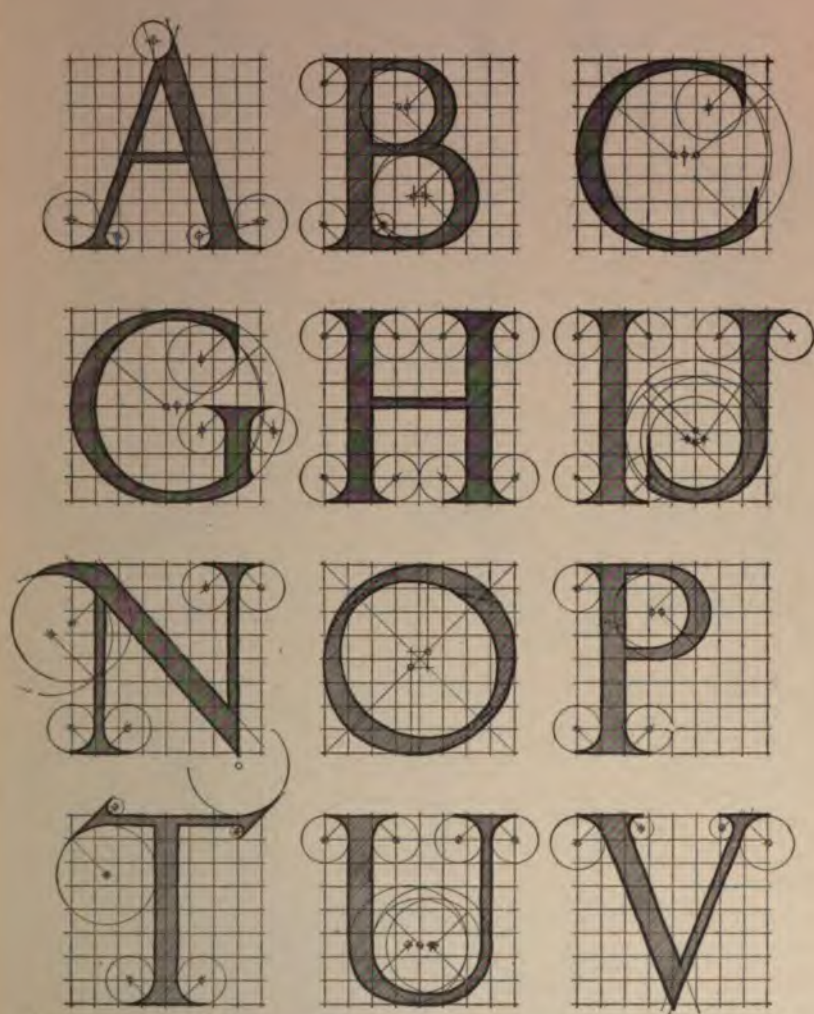
O P Q R S T U V W X Y Z

Architectural Capitals.

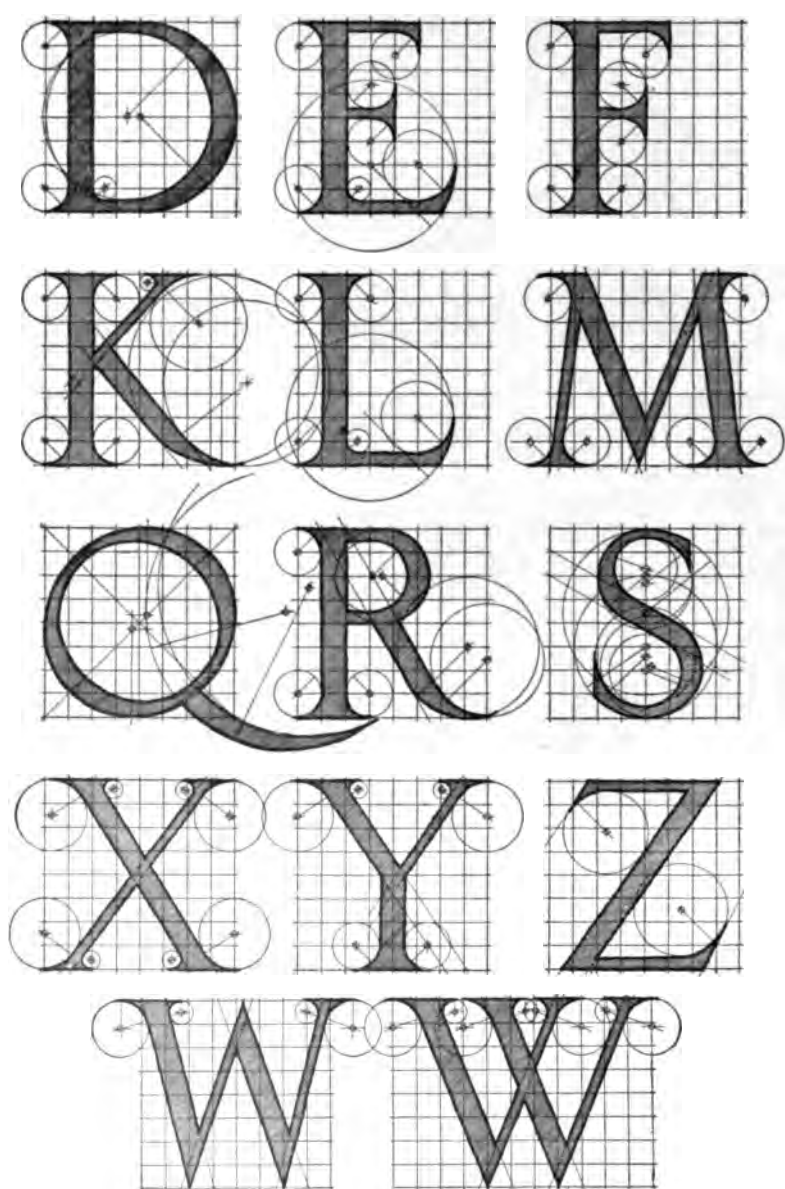
A B C D E F G H I K L M N

O P Q R S T V W X Y Z

Architectural Capitals.



Architectural Alphabet of Classic Renaissance Letters according to Albrecht Durer, adapted and reconstructed by F. C. Brown.



Alphabet of Classic Renaissance Letters—Continued.

MECHANICAL DRAWING.

PART II.

PROJECTIONS.

Orthographic Projection is the art of representing an object upon two planes, at right angles to each other, by lines drawn from all points on the edges or contour perpendicular to these planes. The intersections of the perpendiculars with the planes give figures which are called projections of the object.

The two planes are called *planes of projection*, or *coördinate planes*, one being vertical and the other horizontal, as shown in Fig. 1. These planes are sometimes designated V and H respectively. The intersection of V and H is known as the ground line, or G L. If a in Fig. 1

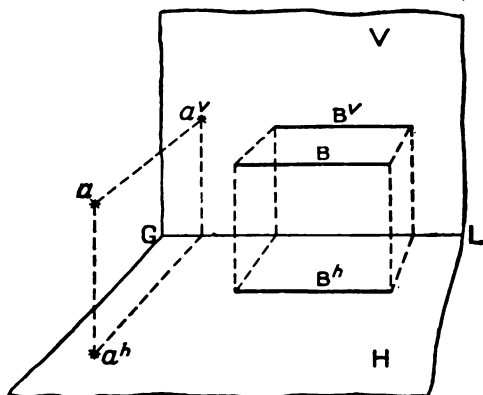


Fig. 1.

is a point in space, and a perpendicular is drawn to the vertical plane, the point a^v will be the projection of the point on the vertical plane, and in a similar way a^h will be the projection of a on the horizontal plane. The line B has its vertical projection at B^v , and its horizontal projection at B^h . Instead of *horizontal* projection and *vertical* projection, the terms **plan** and **elevation** are commonly used. It will be seen from the figure that the plan of a point or line is directly underneath on the H plane, and the elevation directly behind on the V plane.

Suppose in Fig. 2 a cube one inch on a side be placed with the top horizontal and the front face parallel to the vertical plane. Then the plan will be a one-inch square, and the elevation also a one-inch square. In general the plan is a representation of the *top* of the object, and the elevation a view of the *front*. The plan then is a top view, and the elevation a front view. Since the

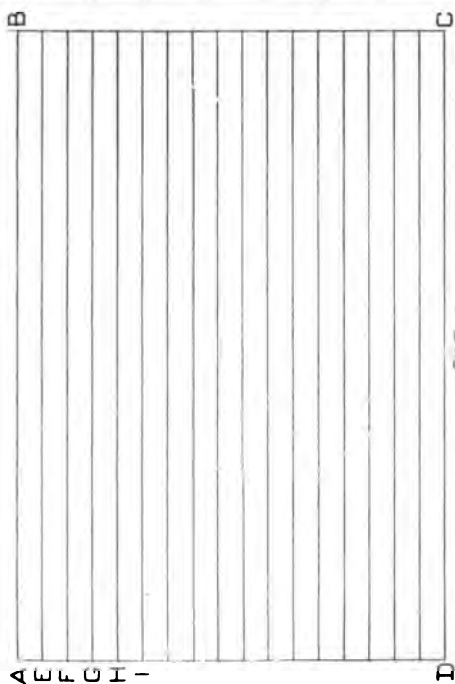
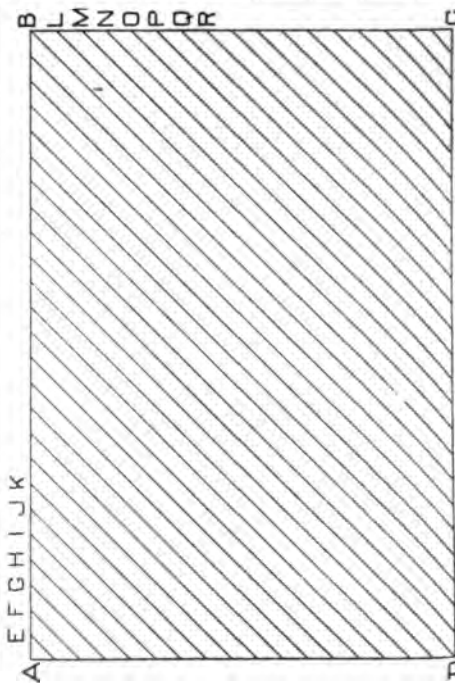


FIG. 1



FIG. 2



LETTERING

THE SUBJECT OF LETTERING IS OF
GREAT IMPORTANCE TO THE MECH-
ANICAL DRAUGHTSMAN. MANY WELL
EXECUTED DRAWINGS HAVE BEEN
DISFIGURED BY POOR LETTERING.

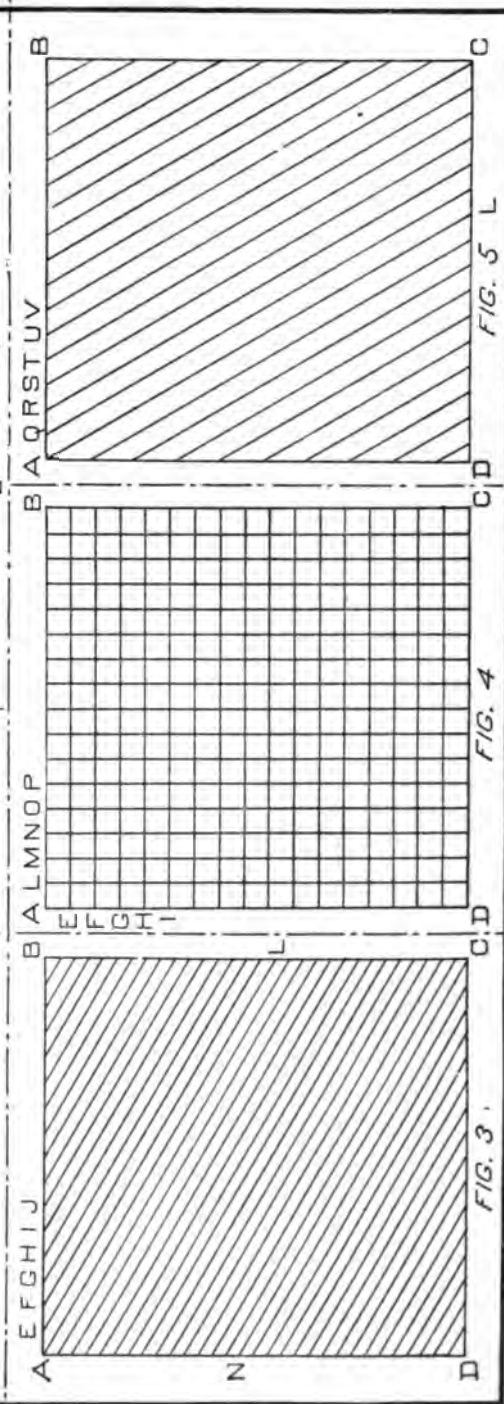
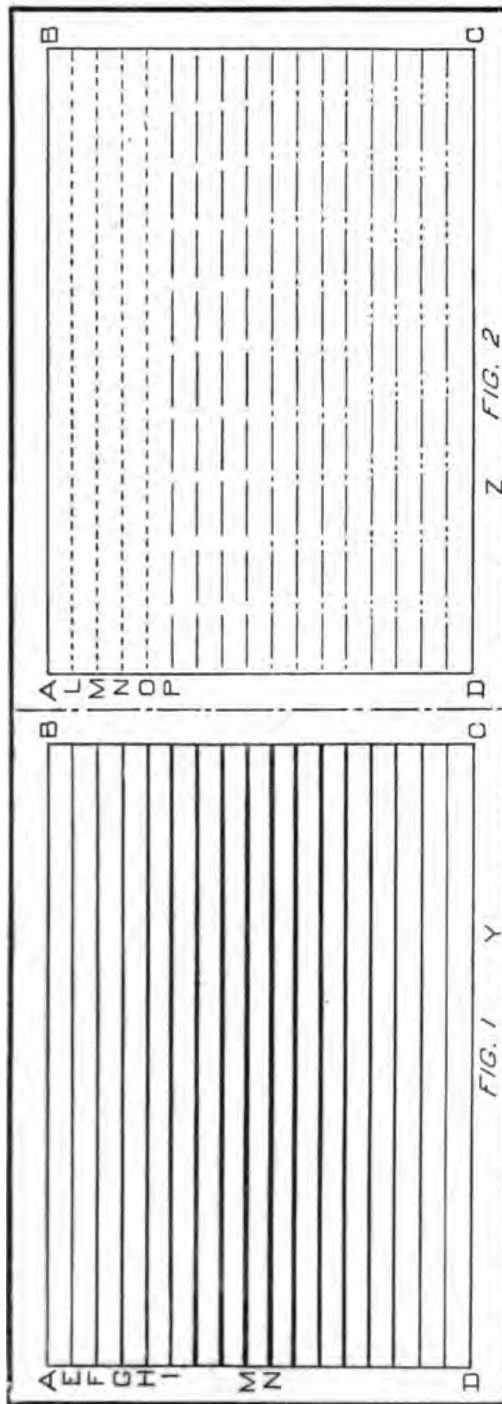
Proficiency can be acquired only
by practice. Practice lettering. Practice.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

1234567890

I II III IV V VI VII VIII IX X



Suppose in Fig. 5, that it is desired to construct the projections of a prism $1\frac{1}{2}$ in. square, and 2 in. long, standing on one end on the horizontal plane, two of its faces being parallel to the vertical plane. In the first place, as the top end of the prism is a square, the top view or plan will be a square of the same size, that is, $1\frac{1}{2}$ in. Then since the prism is placed parallel to and in front of the vertical plane the plan, $1\frac{1}{2}$ in. square, will have two edges parallel to the ground line. As the front face of the prism

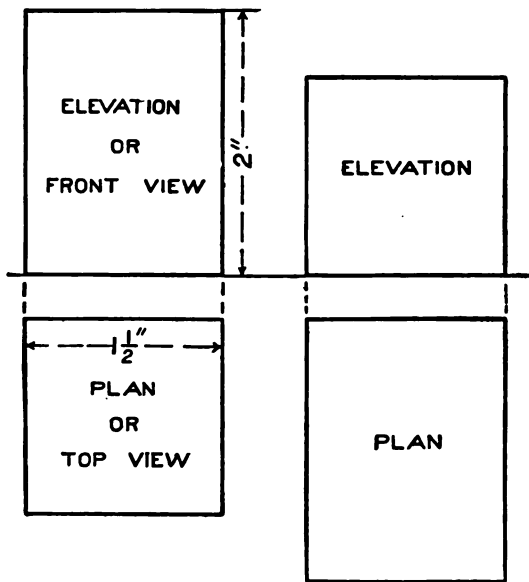


Fig. 5.

is parallel to the vertical plane its projection on V will be a rectangle, equal in length and width to the length and width respectively of the prism, and as the prism stands with its base on H, the elevation, showing height above H, must have its base on the ground line. Observe carefully that points in elevation are vertically over corresponding points in plan.

The second drawing in Fig. 5 represents a prism of the same size lying on one side on the horizontal plane, and with the end's parallel to V.

The principles which have been used thus far may be stated as follows, —

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O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Vertical Roman Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Inclined Roman Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵/₈

Vertical Gothic Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵/₈

Inclined Gothic Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Vertical Roman Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Inclined Roman Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Vertical Gothic Capitals.

A B C D E F G H I J K L M N

O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 & 2⁵₈

Inclined Gothic Capitals.

plan gives the width or thickness, $\frac{1}{8}$ in. Notice that the length of the plan is greater than 2 in. and that varying the angle at

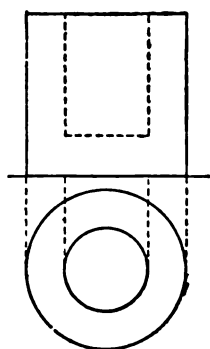


Fig. 12.

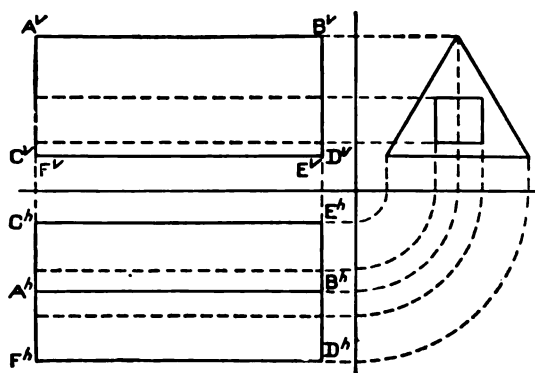


Fig. 13.

which the prism is slanted would change the length of the plan. Now if the prism be turned around through any angle with the vertical plane, the lower edge still being on H, and the inclination

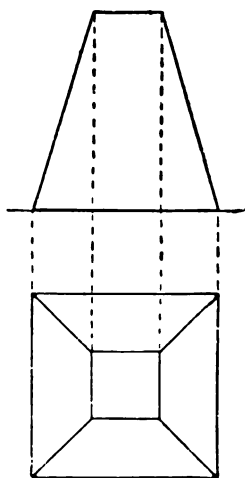


Fig. 14.

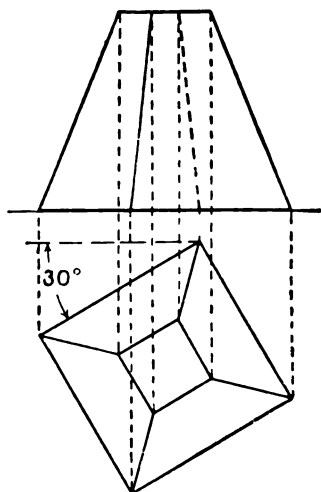


Fig. 15.

of 30° with H remaining the same, the plan must remain the same size and shape.

If the angle through which the prism be turned is 45° , we

have the second plan, exactly the same shape and size as the first. The elevation is found by projecting the corners of the prism ver-

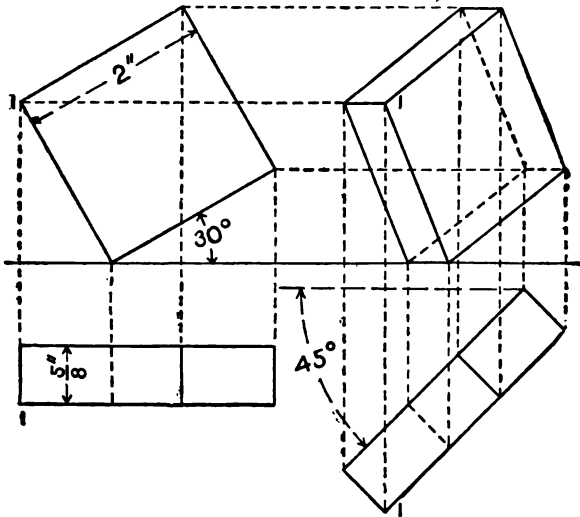


Fig. 16.

tically up to the heights of the same points in the first elevation. All the other points are found in the same way as point No. 1.

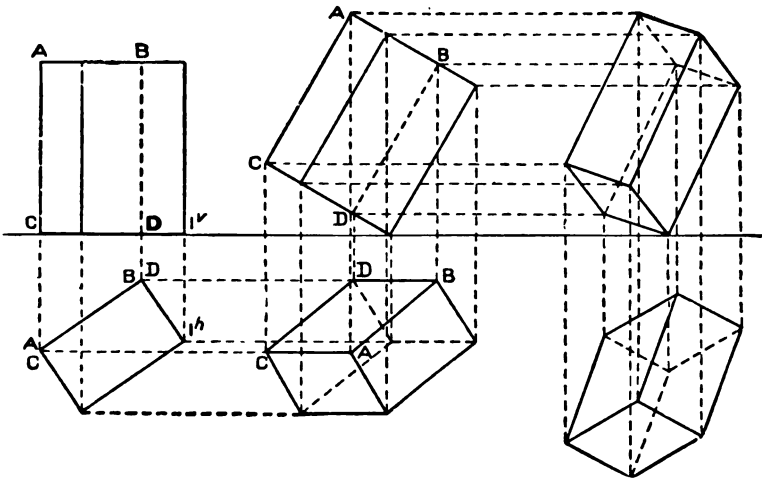


Fig. 17.

Three positions of a rectangular prism are shown in Fig. 17. In the first view, the prism stands on its base, its axis therefore

is parallel to the vertical plane. In the second position, the axis is still parallel to V and one corner of the base is on the horizontal plane. The prism has been turned as if on the line $1^A 1^V$ as an axis, so that the inclination of all the faces of the prism to the vertical plane remains the same as before. That is, if in the first figure the side A B C D makes an angle of 30° with the vertical, the same side in the second position still makes 30° with the ver-

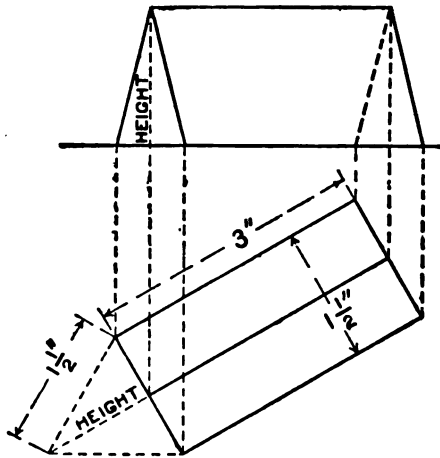
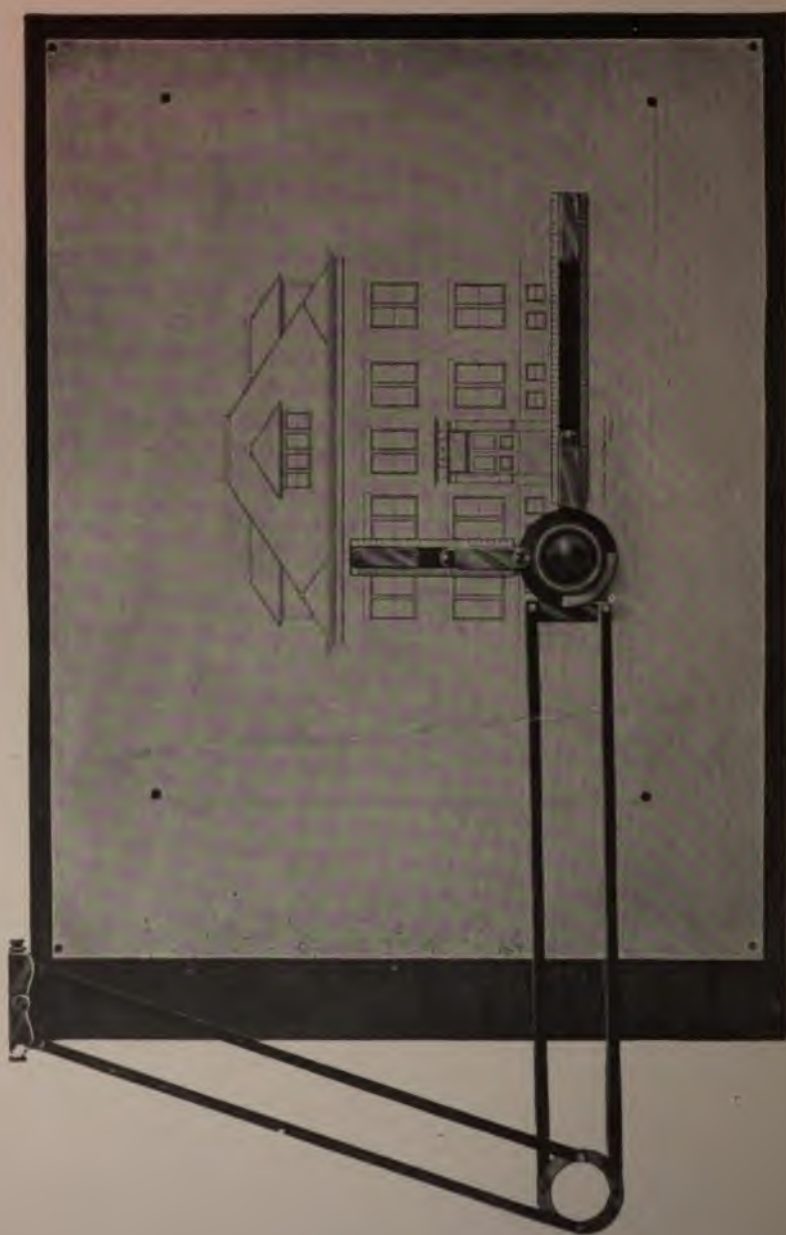


Fig. 18.

tical plane. Hence the elevation of No. 2 is the same shape and size as in the first case. The plan is found by projecting the corners down from the elevation to meet horizontal lines projected across from the corresponding points in the first plan. The third position shows the prism with all its faces and edges making the same angles with the horizontal as in the second position, but with the plan at a different angle with the ground line. The plan then is the same shape and size as in No. 2, and the elevation is found by projecting up to the same heights as shown in the preceeding elevation. This principle may be applied to any solid, whether bounded by plane surfaces or curved.

This principle as far as it relates to heights, is the same that was used for profile views. An end view is sometimes necessary before the plan or elevation of an object can be drawn. Suppose that in Fig. 18 we wish to draw the plan and elevation of a triangular prism 3" long, the end of which is an equilateral triangle

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THE UNIVERSAL DRAFTING MACHINE.

$1\frac{1}{2}$ " on each side. The prism is lying on one of its three faces on H, and inclined toward the vertical plane at an angle of 30° . We

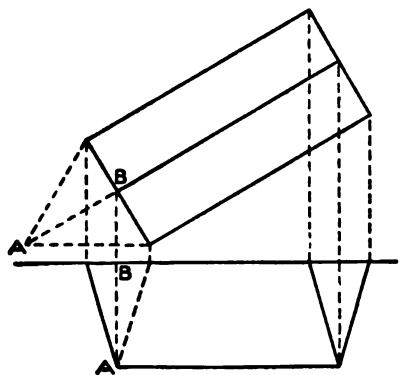


Fig. 19.

are able to draw the plan at once, because the width will be $1\frac{1}{2}$ inches, and the top edge will be projected half way between the other two. The length of the prism will also be shown. Before we can draw the elevation, we must find the height of the top edge. This height, however, must be equal to the altitude of the triangle forming the end of the prism. All that is necessary, then, is to construct an equilateral

triangle $1\frac{1}{2}$ " on each side, and measure its altitude.

A very convenient way to do this is shown in the figure by laying one end of the prism down on H. A similar construction is shown in Fig. 19, but with one face of the prism on V instead of on H.

In all the work thus far the plan has been drawn below and the elevation above. This order is sometimes inverted and the plan put above the elevation.

PLATES.

PLATE V.

The plates of this paper should be laid out the same size as the plates in Part I. The center lines and border lines should also be drawn as shown.

First draw two ground lines across the sheet, 3 inches below the upper border line and 3 inches above the lower border line. The first problem on each ground line is to be placed 1 inch from the left border line and spaces of about 1 inch should be left between the figures.

Isolated points are indicated by a small cross $\times$, and projections of lines are to be drawn full unless invisible. All construction lines should be fine dotted lines. Given and required lines should be drawn full.

Problems on upper ground line;

PROBLEM 1. Locate both projections of a point on the horizontal plane 1 inch from the vertical plane.

PROBLEM 2. Draw the projections of a line 2 inches long which is parallel to the vertical plane and makes an angle of 45 degrees with the horizontal and slants upward to the right.

The line should be 1 inch from the vertical plane and the lower end $\frac{1}{2}$ inch above the horizontal.

PROBLEM 3. Draw the projections of a line $1\frac{1}{2}$ inches long, which is parallel to both planes 1 inch above the horizontal and $\frac{3}{4}$ inch from the vertical.

PROBLEM 4. Draw the plan and elevation of a line 2 inches long which is parallel to H and makes an angle of 30 degrees with V. Let the right-hand end of the line be the end nearer V, $\frac{1}{2}$ inch from V. The line to be 1 inch above H.

PROBLEM 5. Draw the plan and elevation of a line $1\frac{1}{2}$ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. The lower end of line is $\frac{1}{2}$ inch above H.

PROBLEM 6. Draw the projections of a line 1 inch long which is perpendicular to the vertical plane and $1\frac{1}{2}$ inch above the horizontal. The end of the line nearer V, or the back end, is $\frac{1}{2}$ inch from V.

PROBLEM 7. Draw two projections which shall represent a line oblique to both planes.

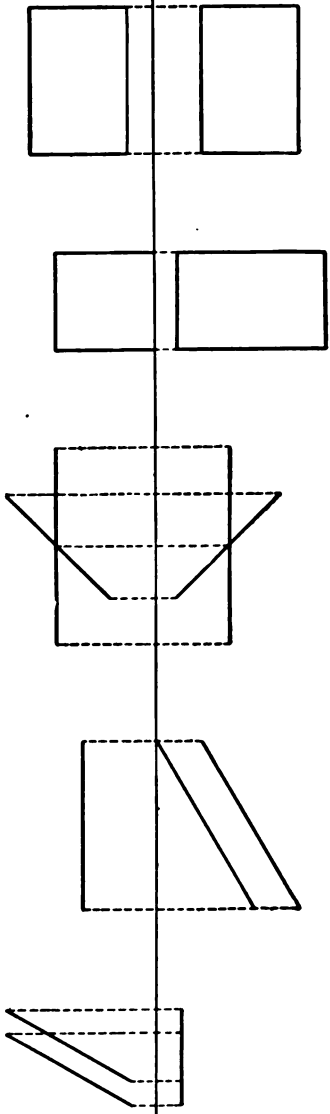
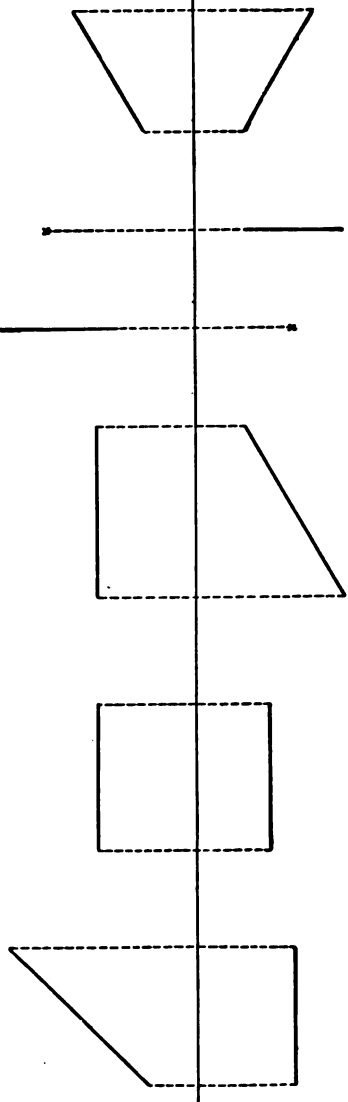
NOTE: Leave 1 inch between this figure and the right-hand border line.

Problems on lower ground line.

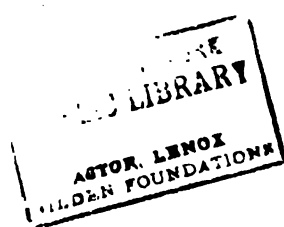
PROBLEM 8. Draw the projections of two parallel lines each $1\frac{1}{2}$ inches long. The lines are to be parallel to the vertical plane and make angles of 60 degrees with the horizontal. The lower end of each line is $\frac{1}{4}$ inch above H. The right-hand end of the right-hand line is to be $2\frac{3}{4}$ inches from the left-hand margin.

PROBLEM 9. Draw the projections of two parallel lines each 2 inches long. Both lines to be parallel to the horizontal and make an angle of 30 degrees with the vertical. The lower line to be $\frac{3}{4}$ inch above H and one end of one line to be against V.

PROBLEM 10. Draw the projections of two intersecting lines. One 2 inches long to be parallel to both planes 1 inch



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above H and $\frac{3}{4}$ inch from the vertical, and the other to be oblique to both planes and of any desired length.

PROBLEM 11. Draw plan and elevation of a prism 1 inch square and $1\frac{1}{2}$ inches long. The prism to have one side on the horizontal plane and the long edges perpendicular to V. The back end of the prism is $\frac{1}{4}$ inch from the vertical plane.

PROBLEM 12. Draw plan and elevation of a prism the same size as given above, but with the long edges parallel to both planes, the lower face of prism parallel to H and $\frac{1}{4}$ inch above it. The back face to be $\frac{1}{2}$ inch from V.

PLATE VI.

The ground line is to be in the middle of the sheet, and the location and dimensions of the figures are to be as given. The first figure shows a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. The second figure is the end or profile projection of the block. The same face is on H in all three positions. Be careful not to omit the shade lines, and try to see why each one is put on.

PLATE VII.

Three ground lines are to be used on this plate, two at the left, $4\frac{1}{2}$ " long and 3" from top and bottom margin lines, and one at the right, half way between the top and bottom margins, $9\frac{1}{2}$ " long.

The figures 1, 2, 3 and 4 are examples for finding the true lengths of the lines. Begin No. 1 $\frac{3}{4}$ " from the border, the vertical projection $1\frac{3}{4}$ " long, one end on the ground line, and inclined at 30° . The horizontal projection has one end $\frac{1}{2}$ " from V and the other $1\frac{1}{2}$ " from V. Find the true length of the line by completing the construction commenced by swinging the arc, as shown in the figure.

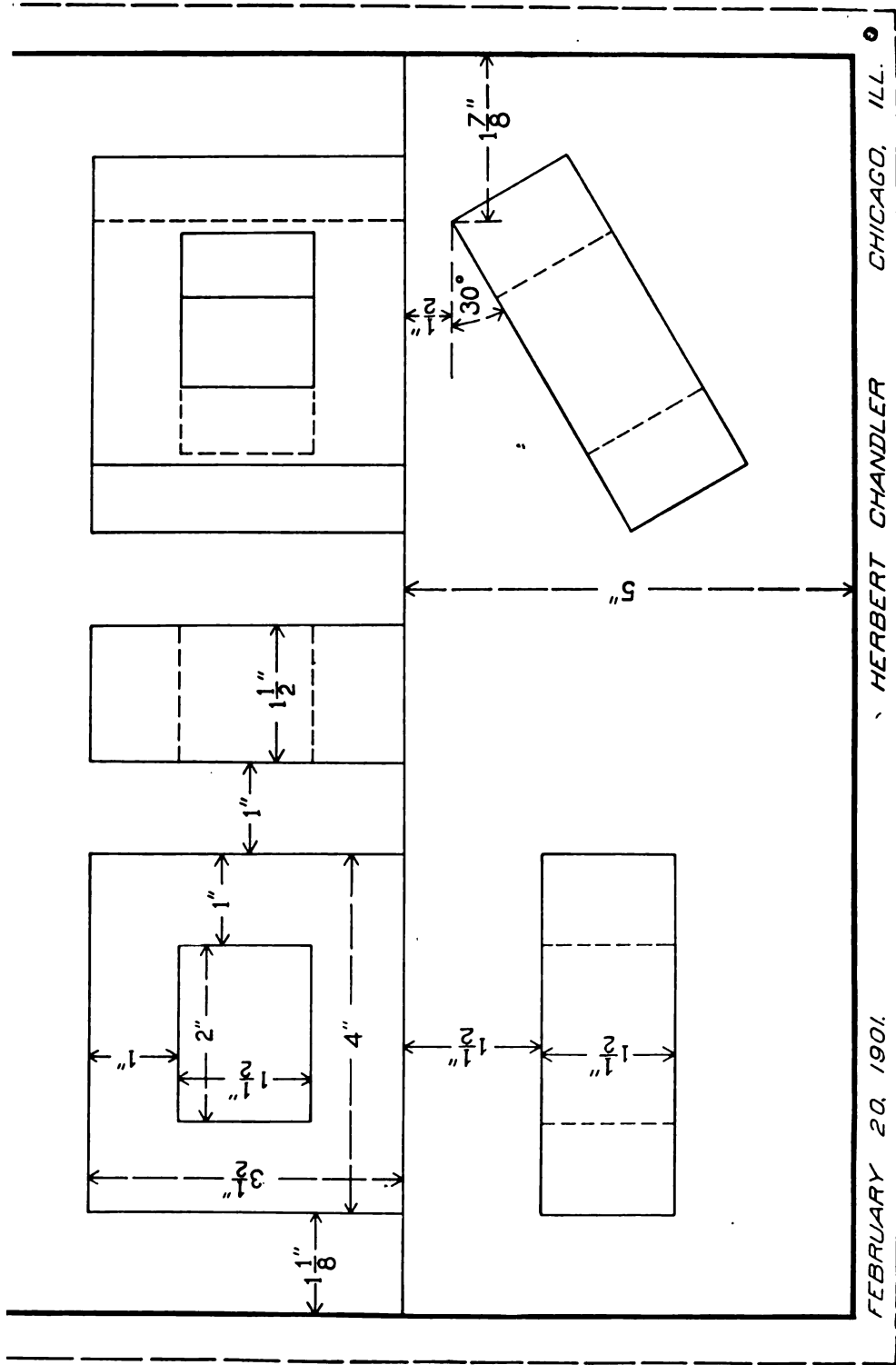
Locate the left-hand end of No. 2 3" from the border, 1" above H and $\frac{5}{8}$ " from V. Extend the vertical projection to the ground line at an angle of 45° , and make the horizontal projection at 30° . Complete the construction for true length as commenced in the figure.

In figures 3 and 4 the true lengths are to be found by completing the revolutions indicated. The left-hand end of Fig. 3 is $\frac{3}{4}$ " from the margin, $1\frac{1}{2}$ " from V and $1\frac{3}{8}$ " above H. The horizontal projection makes an angle of 60° and extends to the ground line, and the vertical projection is inclined at 45° .

The fourth figure is 3" from the border and represents a line in a profile plane connecting points *a* and *b*. *a* is $1\frac{1}{4}$ " above H and $\frac{3}{4}$ " from V, and *b* is $\frac{1}{4}$ " above H and $1\frac{1}{2}$ " from V.

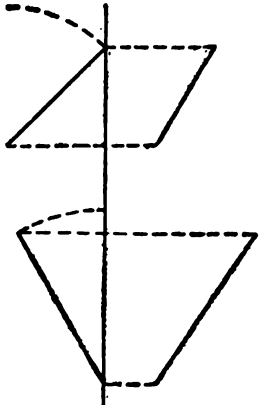
The figures for the middle ground line represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical and base $\frac{5}{8}$ " above the horizontal. The height of pyramid is $2\frac{1}{2}$ " and the diameter of the circle circumscribed about the base is $2\frac{1}{2}$ ". The center of the circle is 6" from the left margin and $1\frac{3}{4}$ " from V. Spaces between figures to be $\frac{3}{4}$ ".

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis through an angle of 15° . The axis of the pyramid, shown dotted, is therefore at 75° . The method of obtaining 75° and 15° with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position, hence the vertical projection will be the same shape and size as before. The points on the plan are found on T-square lines through the corners of the first plan and directly beneath the points in elevation. In the third position the pyramid has been swung around about a vertical line through the apex as axis through 30° . The angle with the horizontal plane remains the same, consequently the plan is the same size and shape as in the second position, but at a different angle with the ground line. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation. Shade lines are to be put on between the light and dark surfaces as determined by the 45° triangle.

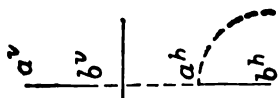


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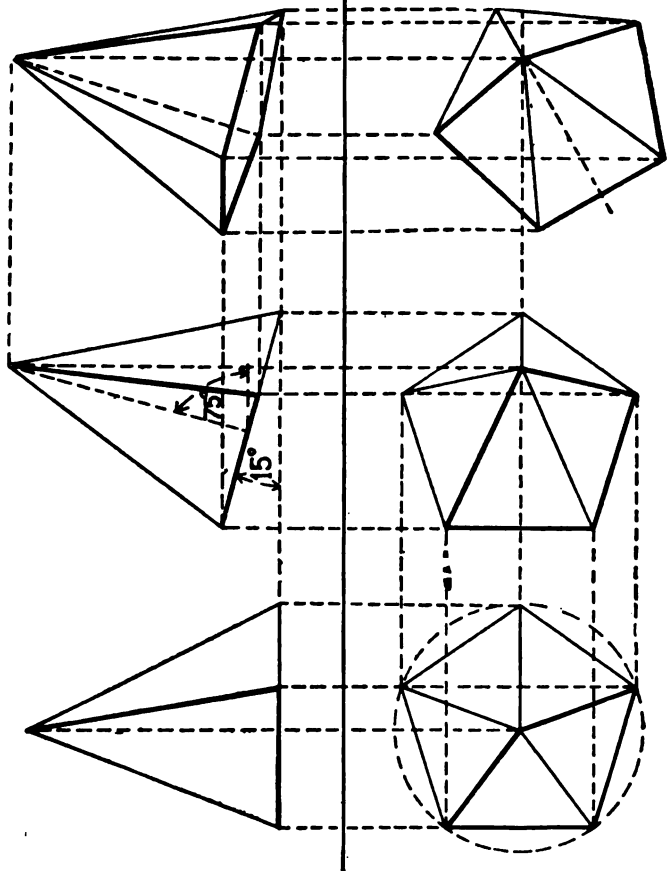
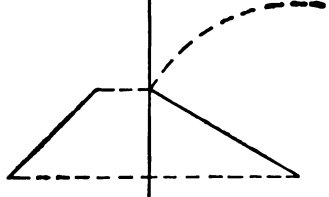
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MECHANICAL DRAWING.

PART III.

WORKING DRAWINGS.

In Mechanical Drawing Parts I and II, instruments and materials are described and some hints given regarding the use of compasses, line pen, triangles, T-square, etc. In addition, the general principles upon which all Mechanical Drawing depends, are explained. After completing this work the student should be able to draw neatly and accurately and apply the fundamental principles.

Let us now take up the subject of working drawings and see how the principles of orthographic projection are made of practical use. We shall see, as we go on, that to a great extent the theoretical principles already learned in the study of projections are used in practical working shop drawings. Nevertheless, there are certain instances in which actual practice differs slightly from the theory.

We shall also find that all draftsmen do not follow the same customs in the matter of minor details, but that in many cases there are several ways of representing objects, all of which may be equally correct, one draftsman using one method either because he prefers it or because it best serves the purpose for which his particular work is being done, while another draftsman uses a different method. The more important principles and customs, however, are pretty well established.

A study of the subject of working drawings should, first, teach us the methods of the best drafting rooms; second, should train our judgment to decide how best to represent the particular object which we have to draw; third, should train our hand and eye to make a clear, neat and well-executed drawing, without unnecessary expenditure of time.

Definition of Working Drawing. A working drawing of any object is a drawing which completely describes the object in every particular, showing its form, size, material, finish, and all other details, so that a workman may take the drawing and without any further instructions make the object exactly as the draftsman intended it to be made. The drawing is, therefore, a sort of language, by which the man who designs the object describes it to the

man who is to make it. Fig. 1 shows the working drawing of a bell crank lever. The drawing itself shows the shape and the dimensions show the size.

Aside from drawings of buildings, etc., that is Architectural drawings, the greater part of the working drawings which are made are for machines, and we will consider chiefly the latter, or, as they are called, machine drawings. These drawings are almost always orthographic projections, as this is by far the easiest and best way to represent a machine or a part of a machine. Some-

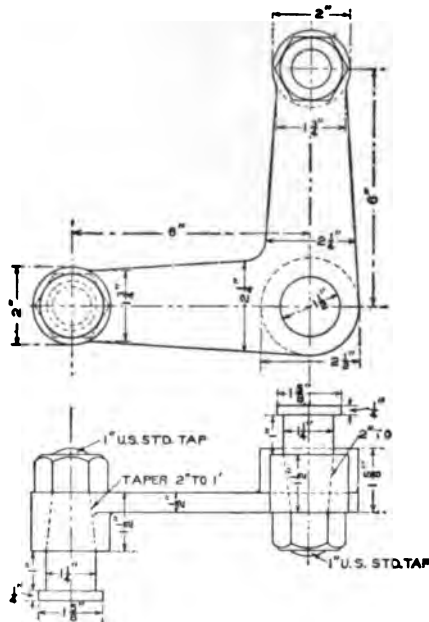


Fig. 1.

times, when it is desired to give a sort of bird's-eye view of a machine, an isometric or an oblique projection is made, but this method involves so much labor that it is seldom used.

Lines. In order to make a drawing perfectly clear, and to avoid confusing one line with another, different kinds of lines are used for different purposes. Fig. 2 shows the six most common kinds used. The ordinary *full lines* are used to represent visible lines of the object which is being drawn.

The *invisible lines* are used to represent lines of the object which would be hidden from sight if a person looked in the direction in which he imagines himself to be looking while he is drawing it.

The use of the *shade lines* will be explained later.

Center lines are used to connect different views of an object, the line being drawn through the center of the piece and extending through both views. Locations of holes are usually shown by having two center lines drawn at right angles to each other through their centers, and the position of these center lines located. Wherever a dimension is to be given to the center of a piece a center line is drawn through the piece and the dimension given to this line.

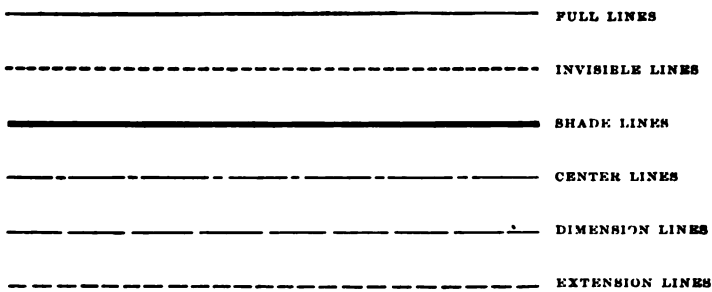


Fig. 2.

Extension lines are sometimes used to connect two views of a piece, but, wherever it is possible to use a center line, instead, the latter is preferable. The principal use of extension lines is, as the name implies, to extend the lines of the object so as to give dimensions between them.

Dimension lines are used in giving dimensions from one line or point to another.

The ordinary lines and the invisible lines should be made of the same width; the shade lines should be made considerably heavier, and the center lines, extension lines and dimension lines should be lighter.

Location of Views. In our preceding study of projections we imagined our object to be held in the angle formed by two

planes which intersect at right angles, the planes and the object being supposed to be in the position represented in Fig. 3, the

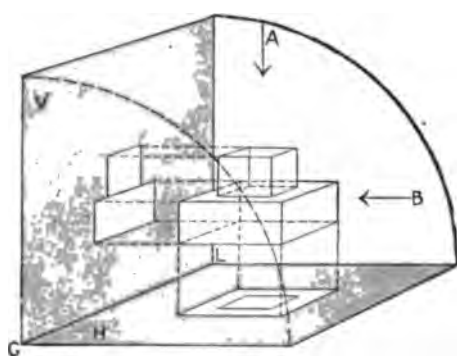


Fig. 3.

horizontal plane H being below the object, and the vertical plane V being beside the object. We then projected down to the horizontal plane and represented there the object as it would appear if seen squarely in the direction indicated by arrow A. We next projected into the vertical plane, and represented the object as it

would appear if the line of vision took the direction of the arrow B. Our planes, with the horizontal and vertical projections of the object on them, when laid out flat, as a sheet of paper is when we actually draw on it, would appear as in Fig. 4, the horizontal projection, or top view, being *underneath* the vertical projection, or side view. This is the practice followed by some draftsmen in making working drawings. Many of the best draftsmen, however, think that it is not as clear and convenient to have the top view of the object underneath the side view, but that it is better to have the view of the top above the other view. Consequently, it is becoming more and more a general custom to suppose the planes to be transparent and to be located with respect to the piece which is being drawn as shown in Fig. 5, the H plane being above the object and the V plane in front of the object. They then draw on the H plane the object as it appears when looking at i

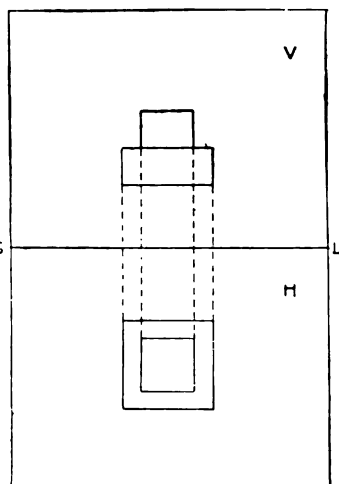


Fig. 4.

through the transparent plane in the direction indicated by arrow C, and on the V plane the object as it appears when looking in direction of arrow D. Now, when the two planes are laid out flat, the top view is above the side view, as in Fig. 6.

Another way of showing this is to suppose the object to be located in a transparent box, and that we look at it from the top and the various sides of the box, and draw on these sides the object as it appears from that side. Then, if the sides of the box are laid out flat, the side view

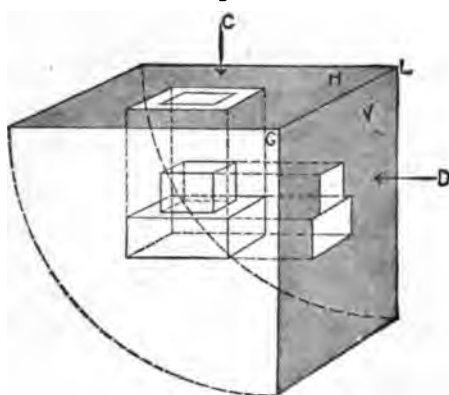


Fig. 5.

will come in the middle, with the top view above, the view of the bottom underneath, the view of the right-hand side on the right, and the view of the left-hand side on the left.

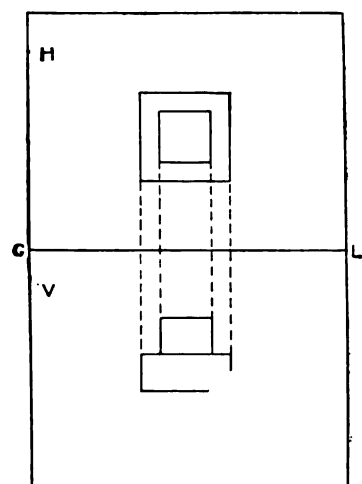


Fig. 6.

From now on, in our work on drawing, we shall follow this rule.

Cross-sections. Very often it occurs that a piece is hollow and the inside construction is more or less complicated, so that if in the drawing the outside view is shown, with the invisible interior drawn in dotted lines, the latter are so confused that the drawing is not easily understood. For this reason it is often convenient to imagine the piece to be cut open, and to

draw it as if we were looking directly at the inside. Such a drawing of a piece is called a cross-section of the piece. The material which must be cut if the object were actually split open is then crosshatched, different kinds of crosshatching being

used for different materials. Fig. 7 shows the kinds of cross-hatching in ordinary use.

Fig. 8 shows a plan and elevation of a simple piece with a hole through it, the hole being shown in the elevation by dotted lines. Fig. 9 shows a plan and a cross-section of the same piece, the cross-section being drawn as if we were looking in the same direction as in the elevation of Fig. 8, but in Fig. 9 the front half is supposed to be cut away and we are looking at the inside of the back half. It will be observed that even on a piece as

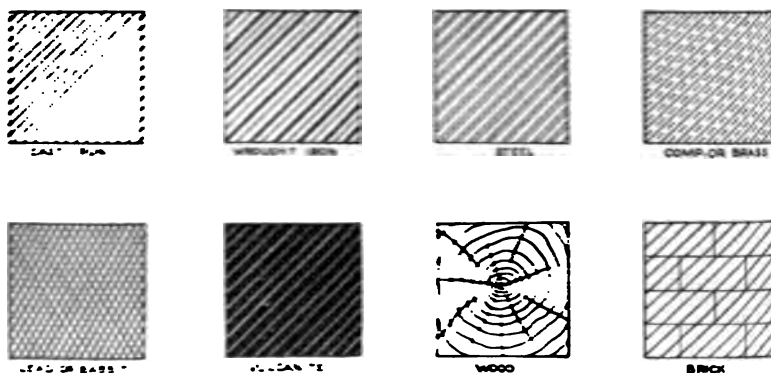


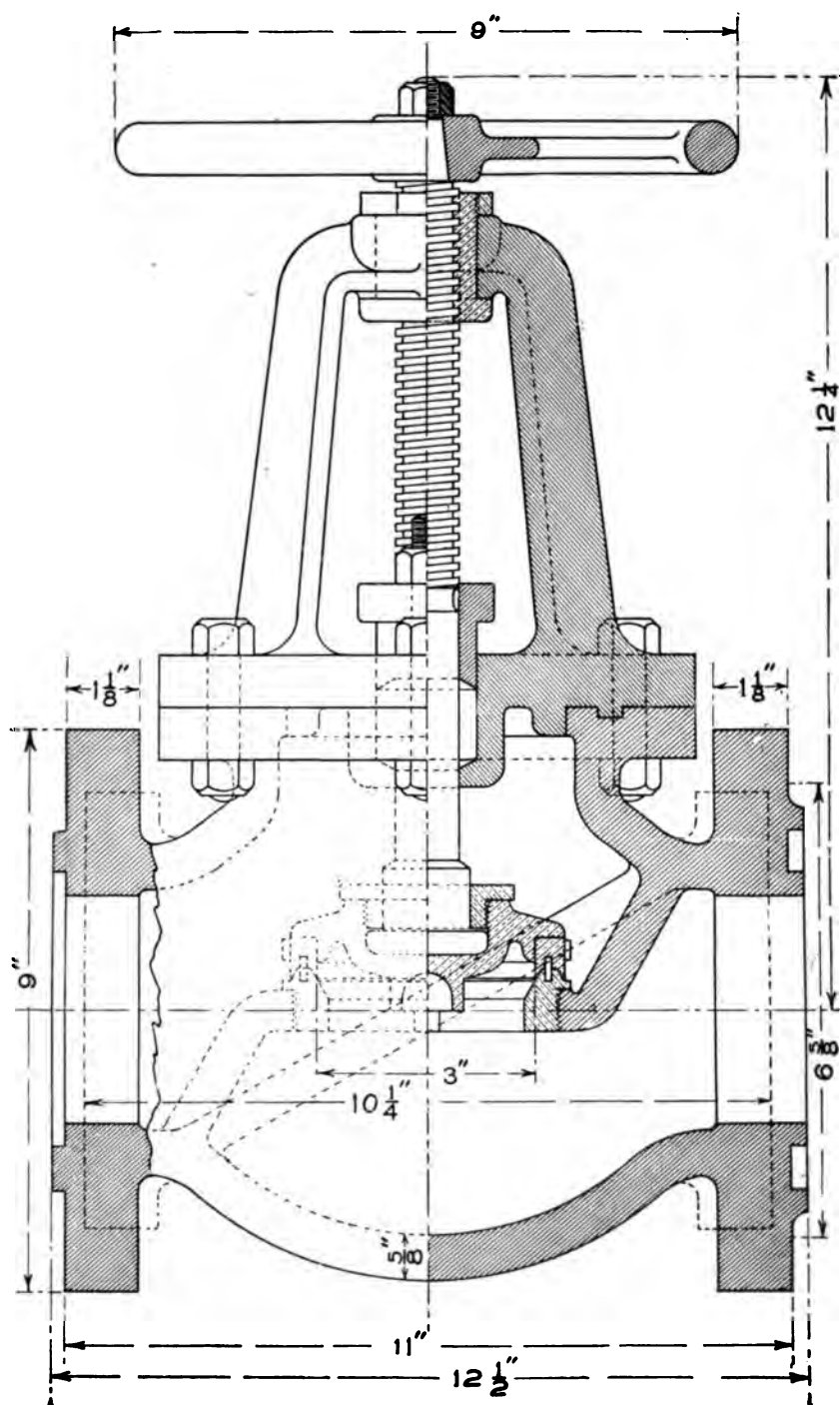
Fig. 7.

simple as the one here shown, the shape of the interior is much clearer in the cross-section than from the elevation, and on a more complicated piece the same will be true to a greater extent.

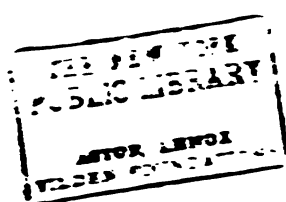
It should be borne in mind that ordinarily in making a cross-section, we show not only those parts of the object which lie in the plane in which it is supposed to be cut, but also all which lie back of that plane.

Sometimes it is desirable to show the inside and the outside of a piece on the same view. Fig. 10 shows the same piece as in Fig. 8, but in Fig. 10 the left-hand half of the lower view is an elevation and the right-hand half is a cross-section, the section and the elevation each extending to the center and being separated by a center line. This is as if one-quarter of it were cut away, the cuts being made along the lines CA and CB of the plan view.

Of course this combination of an elevation and cross-section



WORKING DRAWING SHOWING PRINCIPAL DIMENSIONS OF SPRING SEAT VALVE.
Crosby Steam Gage & Valve Co.



can be used only when the right-hand and left-hand halves of the piece are alike.

Shade Lines. In order to make drawings easier to read, and to make the parts of the object stand out more clearly, shade lines are often put on the drawing. The general principle which determines what lines shall be shade lines is the same as that which governs shade lines already studied under the subject of projections. If, however, this theoretical principle were to be followed out exactly on drawings of machines, and other complicated drawings, it would involve a great deal of time and labor.

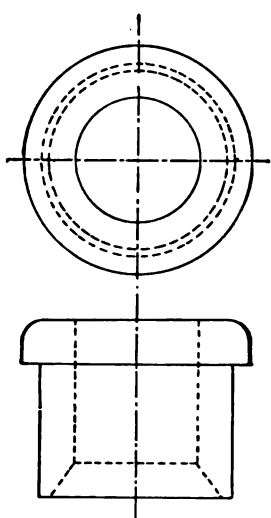


Fig. 8.

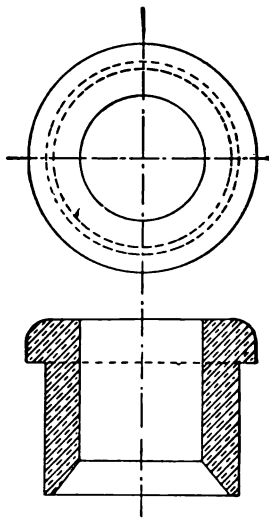


Fig. 9.

Consequently, most draftsmen place shade lines on all lines which represent lower and right-hand edges if these edges are sharp.

The contour lines of cylinders, cones and other rounded surfaces should not be shade lines, although some draftsmen shade them. If the cylinder is drawn in cross-section, however, the edge should be shaded, as the intersection of the plane and cylindrical surface is a sharp edge.

All views are shaded alike, and both are shaded as though they were elevations. The ray of light is supposed to come over

the left shoulder of the draftsman, as he faces the paper, at such an angle that the projection of the ray of light on the drawing paper is in the direction of the arrow in Fig. 11.

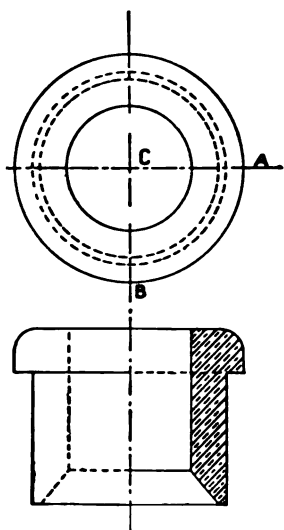


Fig. 10.

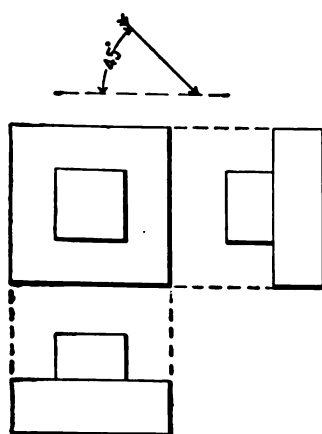


Fig. 11.

Figs. 11 to 18 show some of the most common shapes met with in drawings, and illustrate how the shade lines are placed on each. Fig. 11 is an elevation, plan, and side view of a rectangular

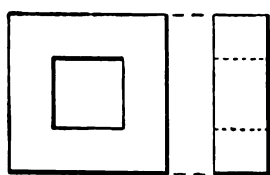


Fig. 12.

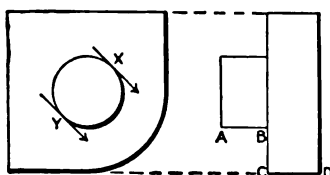


Fig. 13.

prism with a smaller one resting on top of it. Fig. 12 is a plan and side view of a rectangular prism with a rectangular hole through it. It is to be noticed that the shade lines come on the upper and left-hand sides of the hole, since these lines are the

lower and right-hand edges of the material which surrounds the hole. Fig. 13 is a plan and side view of a rectangular prism with one corner rounded, and with a cylinder resting on it. Here the lines A B and C D are not shaded, since they are the contour lines of curved surfaces. In the plan view, the lower right-hand part of the circle, between X and Y, is shaded. To find these points X and Y, draw two lines tangent to the circle and making an angle of 45° with the T-square line as shown by the arrows; X and Y are the points where the arrows are tangent to the circle. Fig. 14 is a plan, elevation and cross-section of a cylinder.

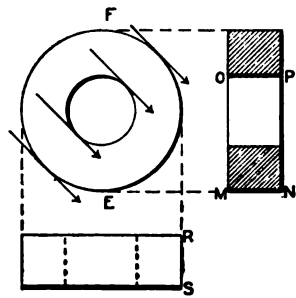


Fig. 14.

Here, in the plan, the larger circle is shaded on the lower side, and the circle which represents the hole is shaded on the upper side. The points where the shade begins are determined as explained for Fig. 13. The lines M N and O P are shaded since,

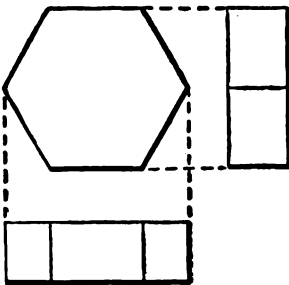


Fig. 15.

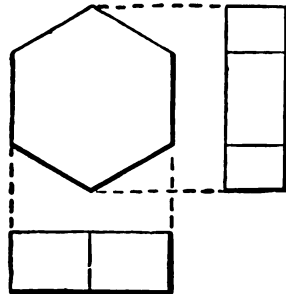


Fig. 16.

as the cylinder is supposed to be cut open, these lines now represent sharp edges. Fig. 15 is a plan, elevation and side view of a hexagonal prism with its long diameter parallel to the bottom of the paper. Fig. 16 is the same except that here the short diameter of the prism is parallel to the bottom of the paper. Fig. 17 is a plan and end view of a rectangular block with a wide slot of the shape H I J K M L O N, cut through it lengthwise. The main point to which attention should be called here is that the line

CD is shaded, although the slot might be so deep that the light might not strike in there because of the shadow of the projecting lip marked in the side view G H I. Fig. 18 is a cross-section and end view of a circular cylinder with a large hole extending part way through and a smaller hole extending the rest of the way. The small circle in the end view is shaded, although it is so far in that no light could strike it.

The student should study these figures carefully, and before

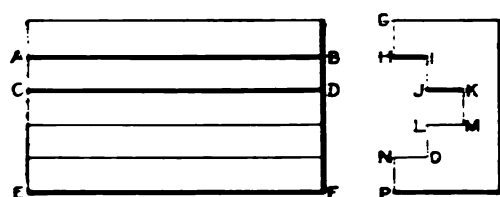


Fig. 17.

leaving them should understand what each figure means and how the shade lines are determined, so that when he meets similar forms in machine drawings he may know where the shade lines should be placed.

Dimensions. In giving the distance from one line to another, a dimension line is drawn between the two lines and arrowheads

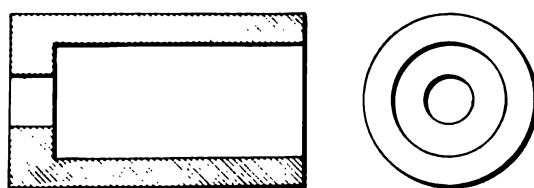


Fig. 18.

are placed at each end of the dimension line; the points of the arrowheads being *exactly on* the lines to which the measurement is being given. At a convenient place between the arrowheads a space is left in the dimension line for the figure.

a plan and elevation of a rectangular piece with a

cylinder on the center of its upper surface, and with four holes through it; the holes being symmetrically located with respect to the center line of the piece; that is, the holes A and B are just as far above the center line E F as C and D are below it, and the holes B and D are just as far to the right of the center line G H as A and C are to the left of it. The fact that the cylinder is on the center of the rectangular piece is shown by the lines E F and G H being drawn through the center of the circle in the plan view, these lines being the center lines both of the cylinder and of the rectangular piece. If the cylinder were not on the center, two other center lines would be drawn through the circle and the dimensions given from each of these lines to the center lines of the rectangular piece, or to the edges of the piece. The fact that the holes are symmetrically located is shown by the dimensions being given between the center lines of the holes and no dimensions being given from these center lines to the center lines of the piece.

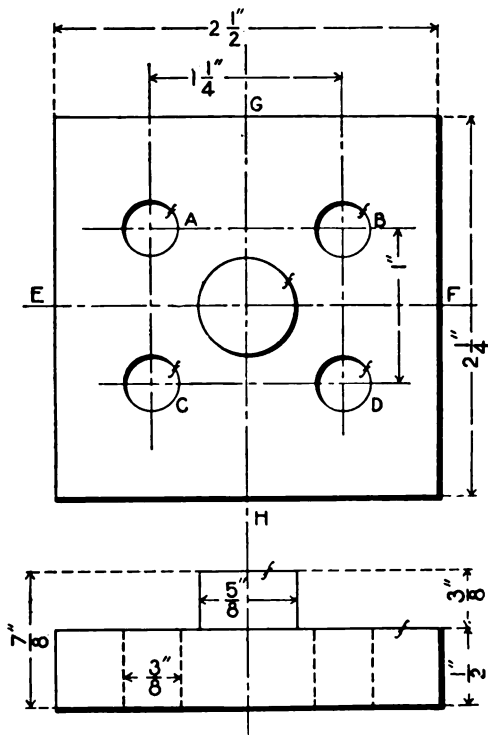


Fig. 19.

Fig. 20 shows how the piece might be dimensioned if the cylinder were not on the center of the rectangular piece and the holes were not symmetrically located with respect to the center of the rectangular piece.

If the centers of a set of holes are so located that a circle can be drawn through them, we always locate the holes by drawing a

center line circle through their centers and giving the diameter of this circle, and if no other dimension than this is given for the location of the holes, it is understood that they are equally spaced around this circle. Fig. 21 illustrates this. If the holes are not equally spaced around the circle, they may be located as shown in Fig. 22.

Diameters of circles and of arcs of circles which are greater than semicircles should be given rather than radii, but if the arc of the circle is less than a semicircle, its radius should be given.

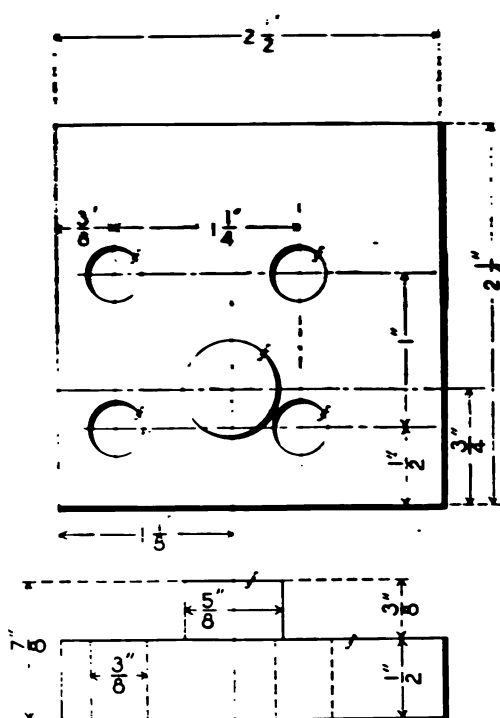


Fig. 20.

Fig. 23 shows how this should be done when the radius is large enough to permit; but if the radius is small, or the dimensions would interfere with other parts of the drawing, it may be done as in Fig. 24.

In Fig. 23 a small circle is drawn (free hand) around the center about which the arc is drawn, and a dimension line carried from the edge of this circle to the arc; an arrowhead being placed on the arc, and the figures placed in the dimension line in the usual way. In this case it is not necessary to put

the letter R (abbreviation for radius) after the dimension. In the two methods shown in Fig. 24 the R should be placed after the figures.

In putting dimensions on a drawing, the figures should be placed to read from only two sides of the paper, usually from the bottom for dimension lines which are horizontal, as the $2\frac{1}{2}$ " dimen-

sion in Fig. 20, and from the right hand for dimension lines which are vertical, as the $2\frac{1}{4}$ " dimension in the same figure. Dimensions should never be placed on center lines if it can be avoided.

If a dimension is given in one view of an object, the same dimension need not be repeated in the other views.

In putting on fractions it is better to have the line which

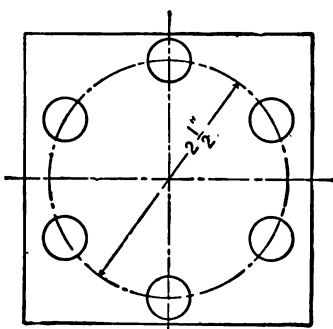


Fig. 21.

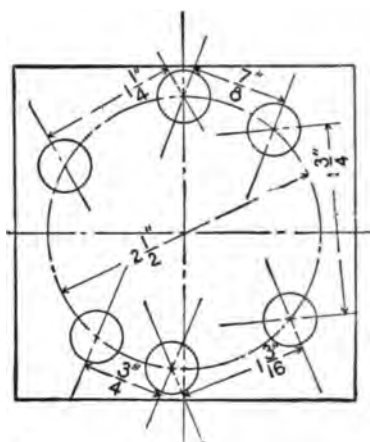


Fig. 22.

divides the numerator and denominator of the fraction extend in the same direction as the dimension line rather than at an angle; that is, the fraction would appear thus, $\frac{1}{2}$, rather than $\frac{1}{2}$.

Finished Surfaces. Since a working drawing is not only to

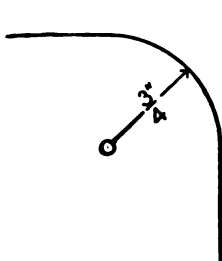


Fig. 23.



Fig. 24.

show the shape and size of the object which it represents, but is to describe it completely, it is essential that there should be some means of distinguishing between the surfaces of the object which are to be left rough as they come from the forge or from the foundry, and the surfaces which are to be finished. Any surface

which has been smoothed off in a lathe, planer, or any machine tool, or has been filed or scraped, is called a finished surface, and is indicated on a drawing by a letter placed on the *edge view* of this surface. In Fig. 19 the whole of the cylindrical part is finished, also the top of the rectangular part. The holes are also finished. The student should notice carefully how the finish marks are used to indicate this fact.

If a piece is to be finished all over, it should be marked "*f* all over." If it is desired to specify what kind of finish is to be put on a surface, that is, whether rough turned, smooth turned, filed, scraped, etc., a note may be made to that effect.

On some conspicuous place on the drawing the words "*f* means finish" should be printed, so that there may be no misunderstanding on the part of a person examining the drawing.

Material. The material of which the piece is to be made should be indicated plainly. If any part of the drawing is a cross-section, the crosshatching might show the material, provided that in some conspicuous part of the drawing a sample of the crosshatching is shown and the material which it represents is stated. It is better, however, to mark on or near each piece, in plain letters, the material of which it is to be made.

Conventional Methods. In drafting, as in many other kinds of work, all unnecessary labor should be avoided. The drawing should give the instructions clearly, but need not be so elaborate as to require unnecessary time in the execution. It frequently happens that if an exact drawing were made representing every line of the object, a great deal of time would be required. Accordingly, if there is any way of representing an object by a few lines only, without sacrificing clearness, it should be used. There are many details such as screw threads, springs, bolts, etc., which occur so frequently on nearly all drawings that easy methods of representation have been universally adopted. In some cases, these ways of representing objects are approximations of the exact drawings and in other cases they are not. Such methods are called conventional methods, or conventions. For some details there is more than one convention, but the same convention should not be used for two different things, nor should several objects of the

same kind on the same drawing be represented conventionally by two different methods.

Screw Threads. The exact drawing of screw threads is a difficult part of mechanical drawing, but enough attention will be given it here to enable the student to make a simple working drawing which includes threads. The common conventional way of drawing a thread is shown in Figs. 25, 26 and 27, Fig. 25 being a single right-hand thread, and Fig. 26 a double right-hand thread.

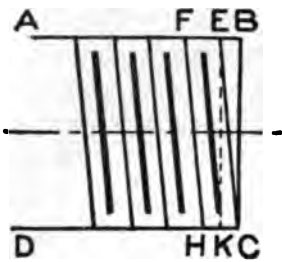


Fig. 25.

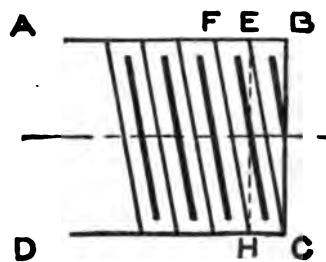


Fig. 26.

First, the plain cylindrical piece ABCD is drawn as if there were no threads upon it. The thread is then indicated by the lines EC, FII, etc., with the shorter and heavier lines between. The lighter lines are all parallel and the same distance apart. This distance is not necessarily the same as the actual pitch of the thread on the screw itself, but is usually $\frac{3}{8}$ inch or $\frac{1}{8}$ inch on drawings of common sizes of bolts. The heavy lines are parallel to the lighter ones and midway between them. The angle which the lines make with the center line of the screw depends on the distance apart of the lines, the slant being such that for a single thread, Fig. 25, a line perpendicular to the center line through one end of one of the lighter lines, as E, will strike the opposite contour of the screw DC, at a point K, which is half way between C and H. To draw the lines so that they will have this slant, choose the distance FE, which is to represent the pitch, and space it off on either of the contour lines, as AB, starting anywhere (in the figure the starting point E is one-half of the distance FE away from B). Next, draw EK per-

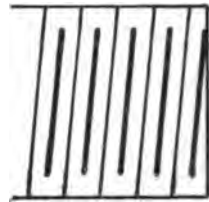


Fig. 27.

pendicular to the center line, thus finding point K, and start the spacing on the contour CD at a distance either side of K equal to $\frac{1}{2}$ FE.

The lighter lines can thus be drawn and the heavy lines put in parallel and half way between. The heavy lines should be a little shorter than the others, and, for the sake of neatness, all should be of the same length. The double thread, Fig. 26, is drawn similarly to the single thread, except that the slant is such that the perpendicular through E will pass through H.

After a little practice the student can draw the threads in this way with his triangles, getting the proper slant and the angle spacing by eye, without the necessity of measuring; he should practice with this end in view, for threads occur so frequently on drawings that the draftsman must be able to draw them rapidly.

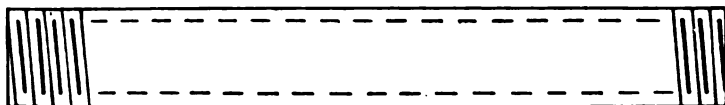


Fig. 28.

Notice should be taken of the fact that if the page be held so that the center lines of the screws in Figs. 25 and 26 are vertical, the lines which represent the threads slant downward from right to left. If the thread is left-handed the lines slant from left to right, as in Fig. 27.

In case of a long screw a few threads may be represented at each end and dotted lines carried the rest of the way, as in Fig. 28.

On any drawing of a screw which is intended for a working drawing, the pitch of the thread, or more commonly the number of threads for an inch of length should be specified; when the thread be standard, it is not always necessary to specify. Even in that case it is well to state the fact that the thread is standard. In giving the number of threads per inch it may be abbreviated, thus 12 THDS, or 12 THI. Examples of this will occur in what follows.

Threaded Holes and Invisible Threads. Fig. 29 shows a piece with a threaded hole in it. The hole is represented in the side view by the four parallel dotted lines. The distance apart of the two outer lines is equal to the diameter of the piece which is to be screwed into the hole. The inner lines are at a distance from

the outer approximately equal to the depth of the thread. In the plan view of the piece (that is, the view looking at the end of the hole) the hole is shown by a full circle of a diameter equal to the distance apart of the inner dotted lines of the other view, and around this full circle a dotted circle whose diameter is equal to the diameter of the bolt; or, in other words, equal to the distance apart of the outer dotted straight lines. The dimension might be given on either view. In the figure it is given on the side view. In giving the diameter of a threaded hole, the diameter of the piece which is to be screwed into the hole is always given. In Fig. 29, the number of threads per inch is not stated, and in this case it would be understood to be standard. Fig. 30 shows another way of dimensioning a tapped hole, which is satisfactory and convenient.

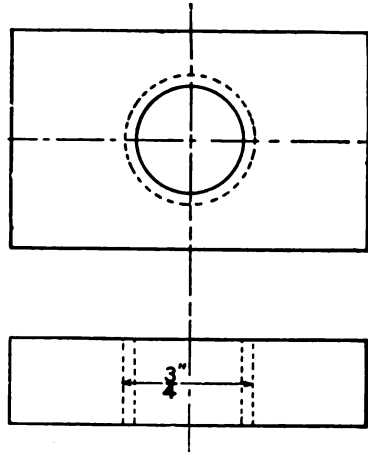


Fig. 29.

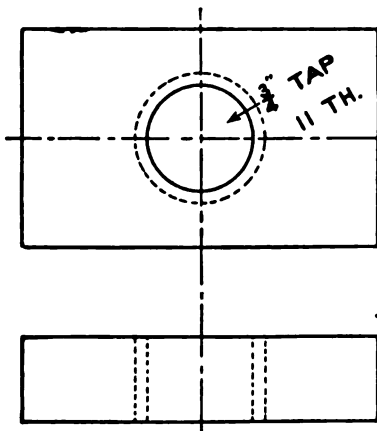


Fig. 30.

Fig. 31 shows the side view of the same piece as Fig. 29, with a part of the screw inserted in the hole. Attention is called to the fact that where the screw is hidden as it goes through the hole the thread is not shown, the parallel dotted lines representing the thread in the same manner as when the hole had no screw in it. Another point to be noted is that the cross-hatching of the broken ends for wrought iron is similar to the representation of the screw

thread and one must learn to judge when the light and heavy lines mean a thread and when they are cross-hatching.

Threads in Sectional Pieces. Figs. 32, 33 and 34 illustrate the common method of representing threads when they occur on pieces which are drawn in cross-section. Fig. 32 is the same piece as Fig. 29, shown cross-sectioned. The front half of the

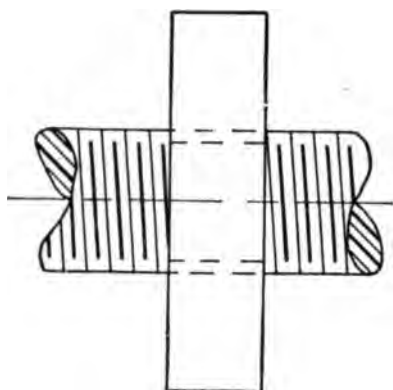


Fig. 31.

piece is supposed to be removed and we are looking at the back half. Now the thread on the back side of a screw slants the opposite way from what it does on the front side, and of course the same is true of the thread in a tapped hole. Consequently, since it is the back side of the hole which is seen, the slant of the lines which represent the thread is opposite to the direction they would have were we looking at the front side of the screw which goes into the hole. We have just learned that for a right-handed thread on a screw the lines slant downward from right to left, and therefore for a right-handed thread seen on the back side of a tapped hole, the lines will slant downward from left to right. In other words, for a right-handed thread in a hole which comes in a cross-section, the lines slant the same as they would on the front of a left-hand thread on a bolt; and for a left-hand thread in a sectioned hole, the slant is the same as for a right-hand thread on a bolt.

Fig. 33 is a piece which has a smooth hole through it and a

thread on the outside. Here the entire thread is invisible, except at the contour of the cylinder, and must be indicated by the notches. These are drawn by spacing off the distance which is used for the pitch and from the points thus found drawing lines with the triangle which make an angle of 60 degrees with the axis of the cylinder. For a single thread the notches on one side have their outer points opposite the inner points of the notches on the

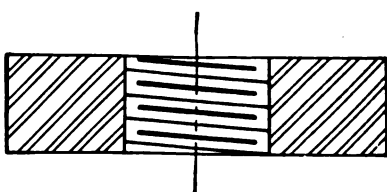


Fig. 32.

other side. For a double thread the notches are directly opposite each other.

Fig. 34 shows two ways of quarter-sectioning a threaded piece, the only difference being that on one the contour of the sectional part is drawn a straight line, while on the other the contour is notched. Either one may be used. The straight contour can, of course, be drawn much more quickly and in places where there is no danger of sacrificing clearness it should be used for that reason. If the drawing is somewhat complicated, so that without the notches it might not be quite clear that the piece was threaded, the notches should be used.

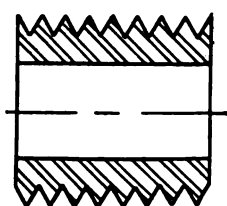


Fig. 33.

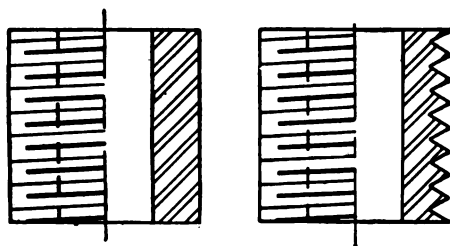


Fig. 34.

As has already been suggested, the student will doubtless find many other customs in the matter of drawing threads which are quite as good as the above. These have been given as ones which are common, and easily drawn. As a matter of convenience the following tables are given, which show the number of threads per inch on some of the most common sizes of bolts, according to the standard adopted by the United States Government, and the Whitworth or English standard.

UNITED STATES STANDARD SCREW THREADS.

Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.
$\frac{1}{2}$	20	$\frac{5}{8}$	11	$1\frac{3}{8}$	6
$\frac{5}{16}$	18	$\frac{3}{4}$	10	$1\frac{1}{2}$	6
$\frac{3}{8}$	16	$\frac{7}{8}$	9	$1\frac{3}{4}$	$5\frac{1}{2}$
$\frac{7}{16}$	14	1	8	$1\frac{7}{8}$	5
$\frac{1}{2}$	13	$1\frac{1}{8}$	7	2	5
$\frac{9}{16}$	12	$1\frac{1}{4}$	7		$4\frac{1}{2}$

WHITWORTH STANDARD SCREW THREADS.

Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.
$\frac{1}{4}$	20	$\frac{5}{8}$	11	$\frac{13}{8}$	6
$\frac{5}{16}$	18	$\frac{3}{4}$	10	$1\frac{1}{8}$	6
$\frac{3}{8}$	16	$\frac{7}{8}$	9	$1\frac{1}{4}$	5
$\frac{7}{16}$	14	1	8	$1\frac{3}{4}$	5
$\frac{1}{2}$	12	$1\frac{1}{8}$	7	$1\frac{7}{8}$	$4\frac{1}{2}$
$\frac{9}{16}$	12	$1\frac{1}{4}$	7	2	$4\frac{1}{2}$

Bolts and Nuts. Among the most common pieces of machinery are bolts and nuts, and the draftsman has frequent occasion to draw them. Fig. 35 is a conventional drawing of a $\frac{1}{2}$ -inch bolt with a hexagonal head and nut. This figure shows the dimensions necessary to be given in order that a workman shall be able to make the bolt from the drawing.

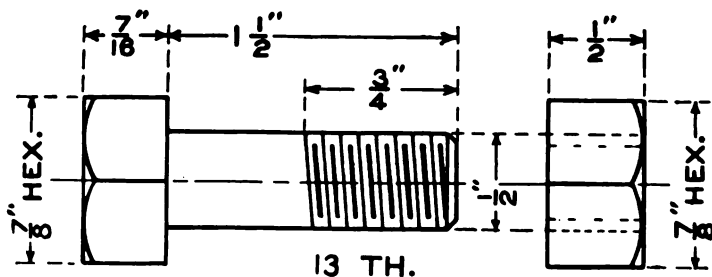


Fig. 35.

Beginning with the head of the bolt, let us study the various parts of this drawing in detail. The head is a hexagonal prism the end of which has been chamfered. We might expect that two views of the head would be necessary to completely define its shape, but the letters HEX printed after the dimension for the diameter of the head indicates that it is hexagonal. In like manner, if the head were square the letters SQ would be placed after the dimension. If two views were drawn, they would appear as in Fig. 36. The head is drawn as if the tool which cut the chamfer, cut off just the corners of the top, so as to make the top a circle tangent to the sides of the hexagon at B, E, G, etc.; the parts BCE, EFG, etc., being portions of a cone or sphere according to the manner of chamfering. The curves ABC and CEF are tangent to the line

GK in the side view, and the lines AJ, CD, and FH are all equal in length. The curves ABC and CEF are properly the lines of intersection of a cone or sphere, as the case may be, with the hexagonal prism, but a convenient and sufficiently accurate way of drawing them is by arcs of circles with the center on the line HJ, half way between HD and DJ, as indicated. The chamfer is represented in the end view by a circle inscribed in the hexagon.

It will be noticed that in Fig. 35 that view of the head is given which shows two faces of the prism, so that the shortest dimension of the hexagon is given. That is, the view is taken in the direction of the arrow L, Fig. 36, instead of in the direction of the arrow M.

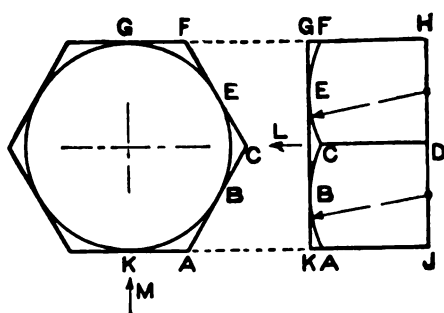


Fig. 36.

This rule should be followed on all detail drawings. The case when it is desirable to give a view in the direction of the arrow M will be discussed later.

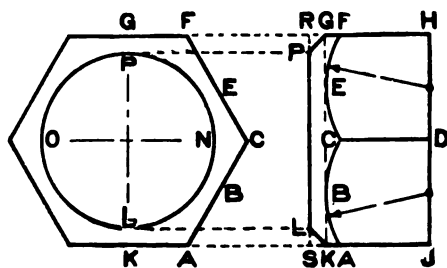


Fig. 37.

Sometimes it is desired to represent the chamfer as being greater, as in Fig. 37. To do this, draw the end view of the hexagon and inside it, of a diameter as much smaller as desired, draw the circle PNLO. Next draw the side view of the hexagonal prism as if there were

no chamfer, as shown at the right (partly in dotted lines). Then from P and L, the upper and lower points of the circle in the other view, draw lines perpendicular to RS and meeting it at P and L. From P and L draw PG and LK, either at an angle of 45 degrees or 30 degrees (the latter being preferable) with RS, and meeting the lines RH and SJ at G and K. Join G and K by a construction line GK (shown dotted but not to be left in the

finished drawing). Draw the arcs ABC and CEF with center on line IJ as shown, and tangent to GK.

Fig. 38 shows the proper way of representing the head which was shown in Fig. 36 if the view is taken in the direction of the arrow M. The dotted construction lines show how the widths are obtained. Fig. 39 shows the corresponding view of the head shown in Fig. 37. The radius with which the middle arc representing the chamfer is drawn in

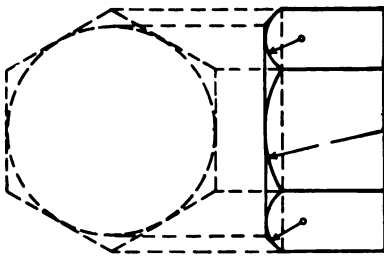


Fig. 38.

these two figures is apparent. Various rules are given for finding a radius for small arcs, but they can be found near enough by trial, after a little experience. The line TV, Fig. 39, to which the tops of the arcs are tangent, is drawn parallel to RS and at a distance from it equal to RG in Fig. 37.

The nut, Fig. 35, is drawn in exactly the same way as the head, so that what has just been said will apply equally well to the nut. The hole in the nut is indicated by the four parallel dotted lines as explained for Fig. 29.

The shank of the bolt is represented with the thread upon it as explained above for conventional threads. The point is drawn chamfered a little in the figure, so that it appears as the frustum of a cone. Bolts often have round points, in which case they would be shown as in Fig. 40. The lines which represent the thread should not cross the line which is drawn square across the bolt to indicate where the chamfer or the rounding of the point begins.

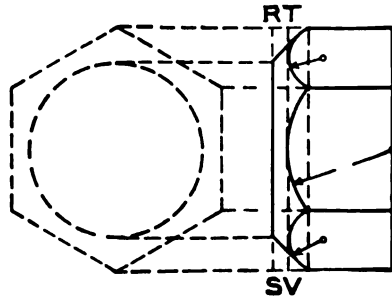


Fig. 39

Fig. 41 shows three views of a square head or nut with chamfer corresponding to that on the hexagonal head in Fig. 36; and Fig. 42 shows the square head or nut chamfered to correspond to

Fig. 37. Referring first to Fig. 41 the arc on the side view which shows the short diameter of the nut is drawn with a radius A, equal to two and one-quarter times the diameter of the bolt on which the head or nut belongs. The arcs on the other side view are drawn with a radius B, equal to one-half of A. The lines EF are drawn from points E tangent to the arcs, and it will be found that the points of tangency will come almost at the points where the arcs cut the lines CD. Points E are found by projecting from the plan view as indicated by the dotted lines. In Fig. 42, the construction is similar. The points N are first found by projecting from the top and bottom of the circle in the plan view; then the lines NL are drawn making angles of 30 degrees with line NN. (The proportions for the radii which are given, hold good only when the angle of 30 degrees is used). Next draw the construction line LL and draw the arc tangent to it with a

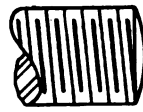


Fig. 40.

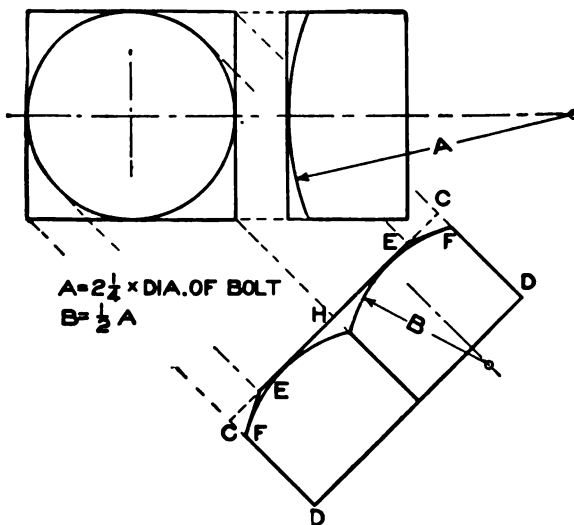


Fig. 41.

radius A equal to two and one-quarter times the diameter of the bolt, the same as in Fig. 41. To draw the chamfer in the other side view, draw the construction line parallel to and at a distance from CC equal to the distance LL from NN and draw the arcs

tangent to this line with radius B equal to one-half of A . The lines EF are then drawn as explained for Fig. 41.

Referring again to Fig. 35, the dimension which shows the length of the bolt under the head should be given to the extreme point of the bolt, as should also the dimension which shows how much of the bolt is threaded.

Most of the bolts in common use are made of standard sizes, that is, for a certain diameter of bolt there is a corresponding standard diameter and thickness for the head and the nut, and a standard number of threads per inch, so that if the bolt which the

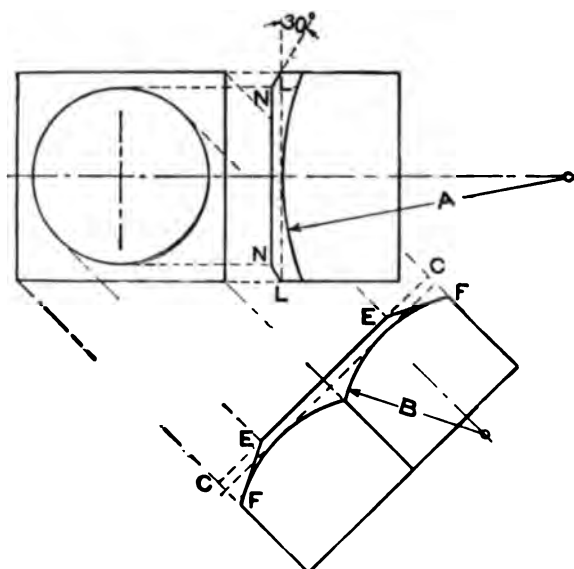


Fig. 42.

draftsman wishes to use has these standard dimensions they may be omitted from the drawing and a note made that the bolt is standard. Then the only dimensions necessary to be given are the diameter, the length under the head, and the length of the threaded part.

The following tables give the United States standard sizes of square and hexagonal heads and nuts for bolts. The columns headed "Width of Nut" and "Width of Head" give the shortest dimension of the square or hexagon, that is, the diameter of the

inscribed circle. The standard number of threads per inch can be found from the table already given.

SQUARE BOLT HEADS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Head.	Thickness of Head.	Dia. of Bolt.	Width of Head.	Thickness of Head.
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	1	$1\frac{5}{8}$	$1\frac{3}{8}$
$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{3}{8}$
$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	2	1
$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{3}{8}$
$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{3}{8}$
$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{9}{8}$	$1\frac{3}{8}$
$1\frac{7}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{1}{2}$	$1\frac{3}{8}$
2	$1\frac{1}{8}$	$\frac{1}{2}$	2	$3\frac{1}{8}$	$1\frac{3}{8}$
$2\frac{1}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{3}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{1}{2}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{3}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{7}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
3	$1\frac{1}{8}$	$\frac{1}{2}$			

HEXAGON BOLT HEADS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Head.	Thickness of Head.	Dia. of Bolt.	Width of Head.	Thickness of Head.
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	1	$1\frac{5}{8}$	$1\frac{3}{8}$
$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{3}{8}$
$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	2	1
$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{3}{8}$
$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{3}{8}$
$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{9}{8}$	$1\frac{3}{8}$
$1\frac{7}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{1}{2}$	$1\frac{3}{8}$
2	$1\frac{1}{8}$	$\frac{1}{2}$	2	$3\frac{1}{8}$	$1\frac{3}{8}$
$2\frac{1}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{3}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{1}{2}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{3}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{7}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
3	$1\frac{1}{8}$	$\frac{1}{2}$			

SQUARE AND HEXAGON NUTS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Nut.	Thickness of Nut.	Dia. of Bolt.	Width of Nut.	Thickness of Nut.
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	1	$1\frac{5}{8}$	1
$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{1}{8}$
$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	2	$1\frac{1}{8}$
$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{1}{8}$
$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{8}$
$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{9}{8}$	$1\frac{1}{8}$
$1\frac{7}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{1}{2}$	$1\frac{1}{8}$
2	$1\frac{1}{8}$	$\frac{1}{2}$	2	$3\frac{1}{8}$	$1\frac{1}{8}$
$2\frac{1}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{3}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{1}{2}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{3}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$			
$2\frac{7}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$			
3	$1\frac{1}{8}$	$\frac{1}{2}$			

Pipes and Pipe Threads. The various kinds of pipe in common use are made to standard sizes, and as the draftsman very often comes in contact with piping we will consider it briefly. The kinds most often used are wrought-iron or steel pipe, brass pipe made to the size of wrought-iron pipe, and cast-iron pipe. The cast-iron pipe is made of different weights and form, according to the purpose for which it is to be used. Standard weight iron pipe is rated by its nominal inside diameter, although the actual diameter does not in most cases quite agree with the nominal diameter.

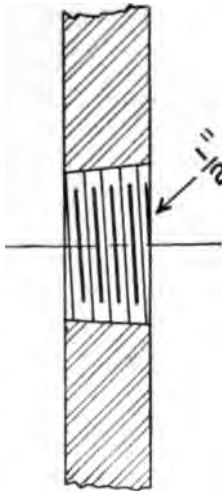


Fig. 43.

A $\frac{1}{4}$ -inch pipe is a pipe, the hole in which is supposed to be $\frac{1}{4}$ inch in diameter, but if carefully measured it will be found to be a few hundredths of an inch larger.

The threads on pipes and pipe fittings are also made to standard; taps and dies are made for various sizes of pipe. These taps and dies are spoken of or described by stating the size of the pipe for which they are intended. For example, a $\frac{1}{4}$ -inch pipe-tap is a tap of the proper size, shape, and number of threads per inch to cut the thread in a hole to receive a $\frac{1}{4}$ -inch pipe.

Threaded holes are made tapering for pipes, the standard taper being $\frac{3}{4}$ inch per foot, that is, the diameter of the hole decreases at the rate of $\frac{3}{4}$ inch per foot. In representing a hole which is threaded with a pipe tap, the hole is drawn of a diameter at its larger end about equal to the outside diameter of the pipe which is to be screwed into it, and is drawn tapering. It is well to make the taper considerably greater than the actual taper, so that the person looking at the drawing may see at a glance that the hole is for a pipe.

The thread is indicated in one of the conventional ways previously explained, but the number of threads per inch and the diameter of the hole need not be given; instead, a note is made

that the hole is tapped for a certain size pipe. Fig. 43 illustrates this.

The following tables of standards for wrought-iron pipe may be found convenient:

STANDARD SIZES OF WROUGHT IRON PIPE.

Nominal Size.	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Actual Inside Diameter.	.27	.364	.494	.623	.824	1.048	1.38	1.610	2.067
Outside Diameter.	.405	.54	.675	.84	1.05	1.315	1.66	1.90	2.375
Nominal Size.	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	6	7	8
Actual Inside Diameter.	2.468	3.067	3.548	4.026	4.508	5.045	6.065	7.023	7.982
Outside Diameter.	2.875	3.50	4.00	4.50	5.00	5.563	6.625	7.625	8.625

STANDARD THREADS FOR WROUGHT IRON PIPE.

Nominal Size of Pipe.	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Threads per Inch.	27	18	18	14	14	$11\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$
Nominal Size of Pipe.	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	6	7	8
Threads per Inch.	8	8	8	8	8	8	8	8	8

Scale Drawings. When the object which is to be drawn is not so large but that it can be easily actual size, or full size as it is called, on a sheet of paper which is of convenient dimensions, it is well, usually, to draw the piece full size. In most cases, however, the machine, or the building, or whatever is to be drawn is so large that it would be impossible to draw it full size. Then the drawing is made to some reduced scale, that is, all the dimensions are drawn smaller than the actual dimensions of the object itself; all dimensions being reduced in the same proportion. For example, if a piece is to be drawn half size, the distance from one point to another on the drawing would be one-half what it is on the piece itself; if the drawing is one-fourth size, the distance on the drawing would be one-fourth what it is on the piece itself,

and so on. In dimensioning such a drawing the dimension which is written on the drawing is the *actual dimension* of the piece, and not the distance which is measured on the drawing. This fact must be very clearly understood by the student.

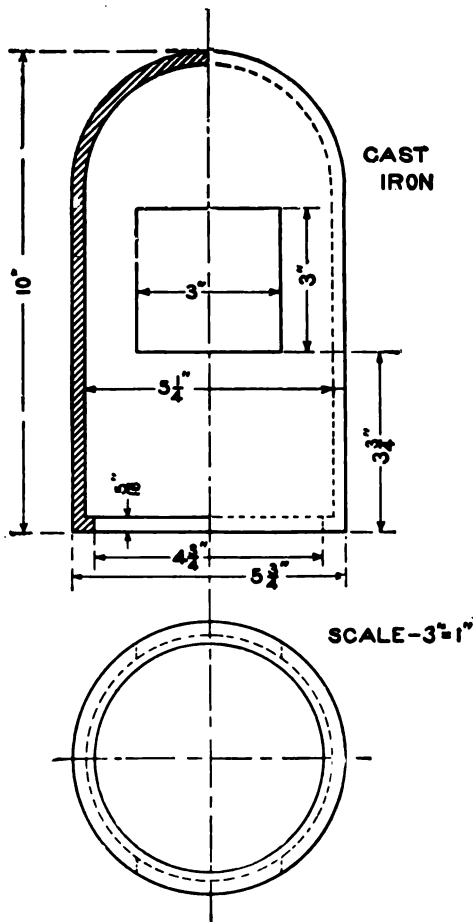


Fig. 44.

foot rule and when we make a measurement on the machine itself we make it with the common foot rule.

Draftsmen's scales can be bought which have different distances thus divided, so that if the draftsman wishes to draw a piece one-fourth size he looks over his scale until he finds a dis-

The common method of reducing all the dimensions in the same proportion is to choose a certain distance and let that distance represent one foot, this distance is then divided into twelve parts and each one of these parts represents an inch; then if half and quarter inches are required these twelfths are subdivided into halves, quarters, etc., until the subdivisions become so small that they cannot be used. We now have a scale which represents the common foot rule with its subdivisions into inches and fractions; but our new foot is smaller than the ordinary distance which we call a foot, and of course its subdivisions are proportionately smaller. When we make a measurement on the drawing we make it with our reduced

tance of three inches (which is of course one-fourth of a foot) divided as explained above, and he uses this to measure with on his drawing. His drawing would then be made to a scale of three inches to the foot. In the same way, if he wishes to make his drawing one-twelfth size he finds on his scale one inch divided into twelfths and fractions of twelfths and uses this as his standard of measurement; if he wishes to make his drawing one forty-eighth size he uses a quarter inch with its subdivisions. Sometimes if the piece to be drawn is very small, the drawing is made at an enlarged scale, such as twice size, three times size, etc.

The mistake of choosing the wrong distance to use on a scale is often made. For example, if he wishes to draw a piece $\frac{1}{4}$ size, he will look over his scale for a place marked $\frac{1}{2}$, and use this for his standard for $\frac{1}{4}$ size, which is wrong. The figure on the scale indicates the distance which is divided up to represent one foot, so



Fig. 45.

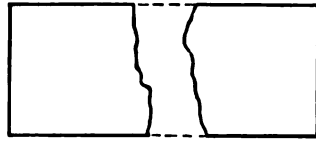


Fig. 46.

that the part of the scale which has $\frac{1}{2}$ marked on it means that $\frac{1}{2}$ of an inch is divided up into twelfths, or in other words, if a drawing is made according to that scale it will be $\frac{1}{24}$ th size.

Every drawing which is made at any other scale than full size should have the scale marked on it plainly.

Fig. 44 shows a piece drawn to a scale of 3 inches per foot, that is, $\frac{1}{4}$ size.

Long Pieces. A piece which is very long in proportion to its diameter or width is often difficult to draw complete, especially if there is much detail to any part of it, for if the scale is made so small that the length will go on a sheet of paper of convenient size the small part is so reduced that it is very small. If such a piece is plain the whole or part of its length, a portion of the plain part may be broken out on the drawing thus shortening the drawing of the piece so that a larger scale may be used. Of course in giving the dimension for the length, the *actual* length must be given. Fig. 45 shows a round piece thus broken out and Fig. 46 a rectangular piece.

It is a good idea to connect by dotted lines the two parts thus broken, although this is not essential.

“Turning Up” a Section. Sometimes a second view of a piece may be avoided by drawing on the first view a partial view showing the shape of the cross-section at the place where drawn. This partial view or “turned-up section” may be drawn in either full or dotted lines and should be cross hatched. If it comes where there are other lines of the original view, as is usually the case, the original lines would be drawn in regardless of the fact that they conflicted with the auxiliary view. Fig. 47 is an illustration.

In General. A working drawing will usually belong to one of the three following classes: *first*, a design of an entirely new machine; *second*, a drawing of a machine which is already built; *third*, a drawing of a new part to fit a machine which is already built, or a drawing of an old machine remodelled.

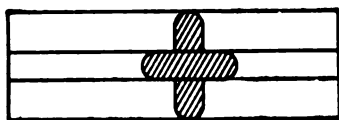


Fig. 47.

In order to design a new machine or a part of a machine, the draftsman must understand the principles of drawing and must also have a clear understanding of the work which the machine is to perform, and must know something of the principles of machine design and the strength of materials. A study of the general manner of proceeding with the drawing, when these things are known, will come later in this course. The draftsman may make a drawing of a machine which is already built, even if he has no understanding of the working of the machine, although under such conditions he works at a great disadvantage. In any case, he must know the principles of drawing.

If the student has learned thoroughly what has preceded in this course, he should be ready to take up the drawing from a machine, and we will now consider the general system to be followed in making such a drawing.

Sketches. In most cases it would be inconvenient for the draftsman to take his drawing board and instruments to the machine and make his careful drawing with the machine close at hand; preferably, he makes what are called sketches, carries his sketches to the drafting room and makes his drawing from them. In making the sketches, each piece of the machine should be

taken separately and a complete working drawing made of it, the only difference between these sketches and the finished drawing being that they are made largely without the use of instruments, triangles, etc.; that is, they are made free hand. The experienced draftsman will draw some lines and circles free hand, and use his instruments on some, according as he may think that he will save time by doing the one or the other; but it is well for the beginner to gain practice by making the sketches, almost wholly free hand, except large circles, and long lines.

The sketches should be neat and perfectly clear, so that if they are laid aside for a long time they can be clearly understood without depending at all upon memory. There is a strong tendency for the beginner to make his sketches hurriedly, thinking that when he comes to finish his drawing he can supply the details from memory. This is a bad plan and will lead to many mistakes. The sketches must be so clear and complete that anyone can read them who has never seen the machine. No attempt need be made to draw them to scale, but **all dimensions**, carefully measured from the machine, should be placed on the sketch.

After every piece of the machine has been thus sketched separately, it is well to make a rough, general sketch of the whole machine, to show how the various pieces fit together, a few of the most important over-all dimensions, distances between centers, etc.

All sketching should be done as rapidly as possible without sacrificing clearness. Before starting to sketch a piece, the draftsman must decide what views are necessary to describe the piece clearly. All sketches should be made large to avoid confusion.

Detail Drawing. After the sketches are made, the next step is the making of the pencil drawing from the sketches, accurately to scale. The size of the plate on which the drawing is to be made is usually fixed by some standard. Where many drawings are made and kept in an office, it is desirable to keep the plates of uniform size, as far as possible. It is good practice to have two or three standard sizes of plates, one for small drawings, one for ordinary-sized work, and one for large drawings; then, whenever a drawing is made, make it on one of these standard plates.

Assuming, then, that we have our paper stretched on the drawing board and the plate laid out, the next step will be to arrange the drawings of the various pieces on the plate so that

there will be room for all and so that they may be properly placed with relation to each other. It may happen that there will not be room on one plate for all the pieces, but that two or more plates will be required. When the parts must be thus arranged on different plates, an effort should be made to keep on the same plate those parts which belong together. For example, if we were drawing a lathe, the details of the parts of the head stock might form one plate, the apron another, and so on.

In locating the various pieces on a plate, they should be placed as nearly as possible in the same relative position to each other that they bear in the machine, except that they are separated. For example: if a nut belongs on the end of a screw, it is desirable to draw it on the same center line with the screw and at the end where it belongs. If a piece is vertical in the machine it should be vertical on the plate, and if horizontal in the machine, it should be horizontal on the plate.

The approximate location of the pieces on the plate may be easily decided by taking a small sheet of paper of about the same proportion as the plate, but perhaps one-fourth or one-half size, and sketching on it roughly the outline of the various pieces. The arranging of the plate should not be allowed to take much time, but should be done as rapidly as possible. After the location of each view of each piece is determined, the pencil drawing should begin *in scale*, with one of the principal pieces. In almost all cases a center line is first drawn. It is better to carry along all the views of a piece at once, instead of completing one view at a time. The piece started should have all its views finished and completely dimensioned before another piece is begun; exceptions to this are sometimes necessary for special reasons. The lines should be drawn accurately, but no attempt need be made to obtain finish; that is, in order to save time, the lines may be run past the point where they should properly stop, etc. Nothing should be omitted, however.

Each plate of details should have a title, stating of what machine it is a drawing, and, if there are several plates, it is well to state also of what part of the machine the plate in question is a drawing. It is also a good idea to print its name beside each of the principal pieces.

Tracing. Having finished the pencil drawing, the next step is the inking. In some offices the pencil drawing is made on a thin, tough paper, called board paper, and the inking is done over the pencil drawing, in the manner with which the student is already familiar. It is more common to do the inking on thin, transparent cloth, called tracing cloth, which is prepared for the purpose. This tracing cloth is made of various kinds, the kind in ordinary use being what is known as "dull back," that is, one side is finished and the other side is left dull. Either side may be used to draw upon, but most draftsmen prefer the dull side. If a drawing is to be traced it is a good plan to use a 3H or 4H pencil, so that the lines may be easily seen through the cloth.

The tracing cloth is stretched smoothly over the pencil drawing and a little powdered chalk rubbed over it with a dry cloth, to remove the slight amount of grease or oil from the surface and make it take the ink better. The dust must be carefully brushed or wiped off with a soft cloth, after the rubbing, or it will interfere with the inking.

The drawing is then made in ink on the tracing cloth, after the same general rules as for inking the paper, but care must be taken to draw the ink lines exactly over the pencil lines which are on the paper underneath, and which should be just heavy enough to be easily seen through the tracing cloth. The ink lines should be firm and fully as heavy as for ordinary work. In tracing, it is better to complete one view at a time, because if parts of several views are traced and the drawing left for a day or two, the cloth is liable to stretch and warp so that it will be difficult to complete the views and make the new lines fit those already drawn and at the same time conform to the pencil lines underneath. For this reason it is well, when possible, to complete a view before leaving the drawing for any length of time, although of course on views in which there is a good deal of work this cannot always be done. In this case the draftsman must manipulate his tracing cloth and instruments to make the lines fit as best he can. A skillful draftsman will have no trouble from this source, but the beginner may at first find difficulty.

Inking on tracing cloth will be found by the beginner to be quite different from inking on the paper to which he has been accustomed, and he will doubtless make many blots and think at

first that it is hard to make a tracing. After a little practice, however, he will find that the tracing cloth is very satisfactory and that a good drawing can be made on it quite as easily as on paper.

The necessity for making erasures should be avoided, as far as possible, but when an erasure must be made a good ink rubber or typewriter eraser may be used. If the erased line is to have ink placed on it, such as a line crossing, it is better to use a soft rubber eraser. All moisture should be kept from the cloth.

Blue Printing. The tracing, of course, cannot be sent into the shop for the workmen to use, as it would soon become soiled and in time destroyed, so that it is necessary to have some cheap and rapid means of making copies from it. These copies are made by the process of blue printing in which the tracing is used in a manner similar to the use made of a negative in photography.

Almost all drafting rooms have a frame for the purpose of making blue prints. These frames are made in many styles, some simple, some elaborate. A simple and efficient form is a flat surface usually of wood, covered with padding of soft material, such as felting. To this is hinged the cover, which consists of a frame similar to a picture frame, in which is set a piece of clear glass. The whole is either mounted on a track or on some sort of a swinging arm, so that it may readily be run in and out of a window.

The print is made on paper prepared for the purpose by having one of its surfaces coated with chemicals which are sensitive to sunlight. This coated paper, or blue-print paper, as it is called, is laid on the padded surface of the frame with its coated side uppermost; the tracing laid over it right side up, and the glass pressed down firmly and fastened in place. Springs are frequently used to keep the paper, tracing, etc., against the glass. With some frames it is more convenient to turn them over and remove the backs. In such cases the tracing is laid against the glass, face down; the coated paper is then placed on it with the coated side against the tracing cloth.

The sun is allowed to shine upon the drawing for a few minutes, then the blue-print paper is taken out and thoroughly washed in clean water for several minutes and hung up to dry.

If the paper has been recently prepared and the exposure properly timed, the coated surface of the paper will now be of a clear, deep blue color, except where it was covered by the ink lines, where it will be perfectly white.

The action has been this: Before the paper was exposed to the light the coating was of a pale yellow color, and if it had then been put in water the coating would have all washed off, leaving the paper white. In other words, before being exposed to the sunlight the coating was soluble. The light penetrated the transparent tracing cloth and acted upon the chemicals of the coating, changing their nature so that they became insoluble; that is, when put in water, the coating, instead of being washed off, merely turned blue. The light could not penetrate the ink with which the lines, figures, etc., were drawn, consequently the coating under these was not acted upon and it washed off when put in water, leaving a white copy of the ink drawing on a blue background. If running water cannot be used, the paper must be washed in a sufficient number of changes until the water is clear. It is a good plan to arrange a tank having an overflow, so that the water may remain at a depth of about 6 or 8 inches.

The length of time to which a print should be exposed to the light depends upon the quality and freshness of the paper, the chemicals used and the brightness of the light. Some paper is prepared so that an exposure of one minute, or even less, in bright sunlight, will give a good print and the time ranges from this to twenty minutes or more, according to the proportions of the various chemicals in the coating. If the full strength of the sunlight does not strike the paper, as, for instance, if clouds partly cover the sun, the time of exposure must be lengthened.

Assembly Drawing. We have followed through the process of making a detail drawing from the sketches to the blue print ready for the workmen. Such a detail drawing or set of drawings shows the form and size of each piece, but does not show how the pieces go together and gives no idea of the machine as a whole. Consequently, a general drawing or assembly drawing must be made, which will show these things. Usually two or more views are necessary, the number depending upon the complexity of the machine. Very often a cross-section through some part of the

machine, chosen so as to give the best general idea with the least amount of work, will make the drawing clearer.

The number of dimensions required on an assembly drawing depends largely upon the kind of machine. It is usually best to give the important over-all dimensions and the distance between the principal center lines. Care must be taken that the over-all dimensions agree with the sum of the dimensions of the various details. For example, suppose three pieces are bolted together, the thickness of the pieces according to the detail drawing, being one inch, two inches, and five and one-half inches respectively; the sum of these three dimensions is eight and one-half inches and the dimensions from outside on the assembly drawing, if given at all, must agree with this. It is a good plan to add these over-all dimensions, as it serves as a check and relieves the mechanic of the necessity of adding fractions.

FORMULA FOR BLUE-PRINT SOLUTION.

Dissolve thoroughly and filter.

- | | | |
|----|------------------------------|------------|
| A. | Red Prussiate of potash..... | 2½ ounces, |
| | Water..... | 1 pint. |
| B. | Ammonio-Citrate of iron.. | 4 ounces, |
| | Water..... | 1 pint. |

Use equal parts of A and B.

FORMULA FOR BLACK PRINTS

Negatives. White lines on blue ground; prepare the paper with

Ammonio-Citrate of iron.....	40 grains,
Water.....	1 ounce.

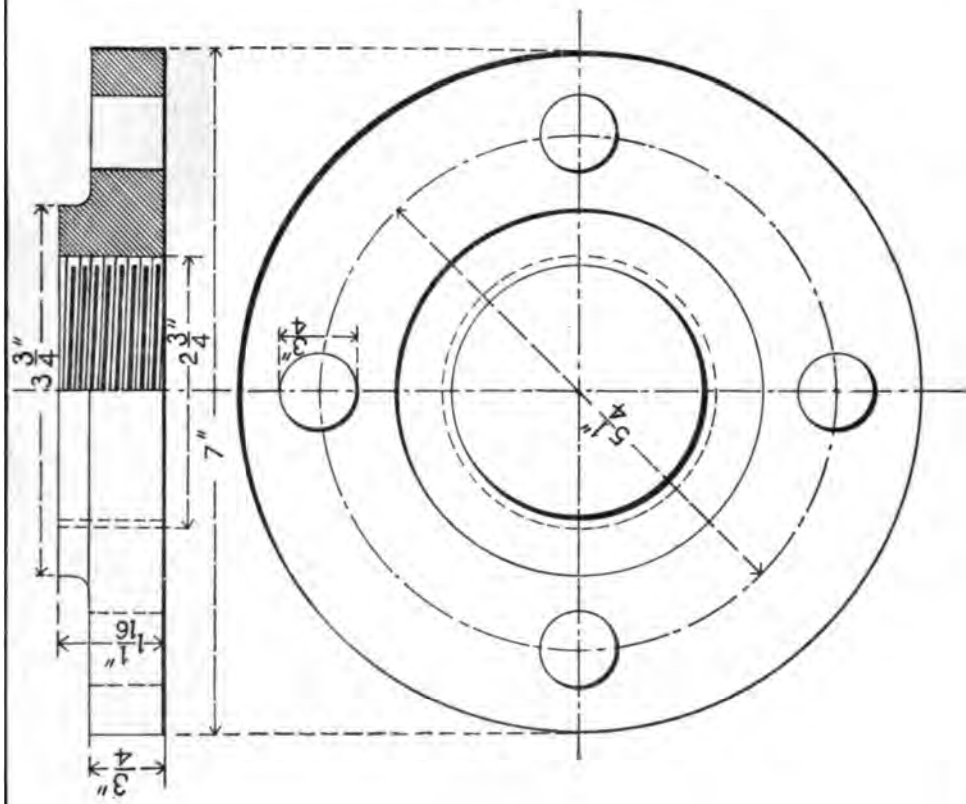
After printing wash in water.

Positives. Black lines on white ground; prepare the paper with:

Iron perchloride....	616 grains,
Oxalic Acid	308 grains,
Water.....	14 ounces.

Develop in { Gallie Acid..... 1 ounce,
Citric Acid..... 1 ounce,
Alum..... 8 ounces

Use 1½ ounces of developer to one gallon of water. Paper is fully exposed when it has changed from yellow to white.



PIPE COUPLING

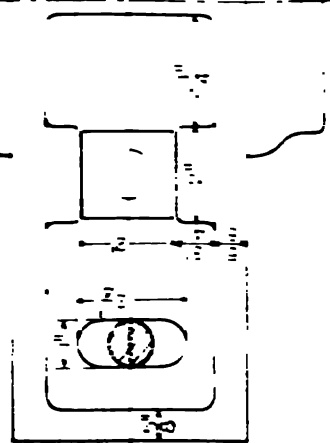
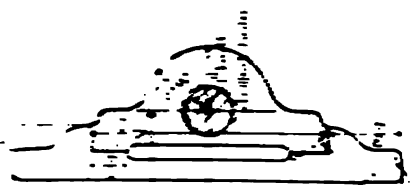
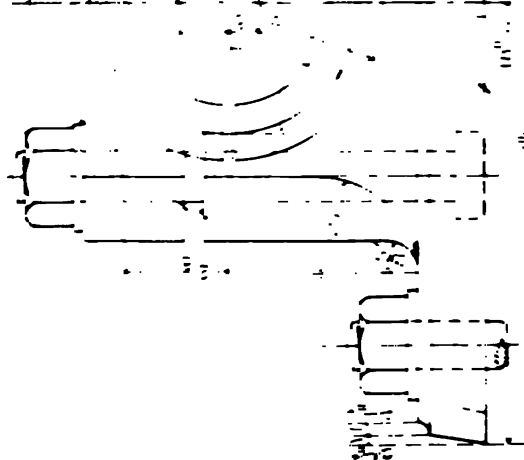
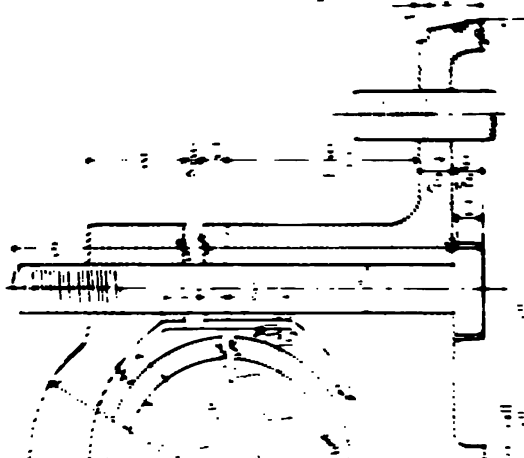
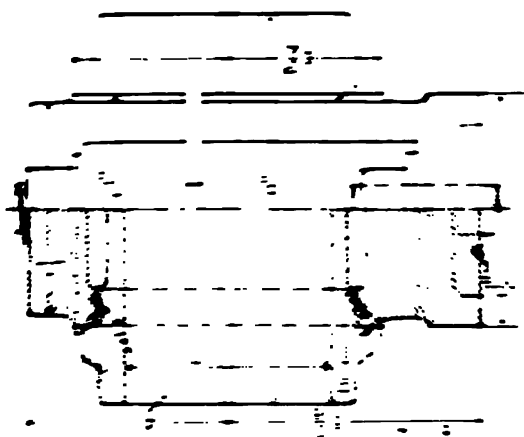
MARCH 27, 1901.

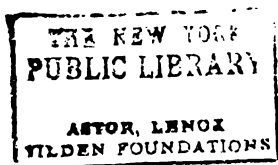
HERBERT CHANDLER

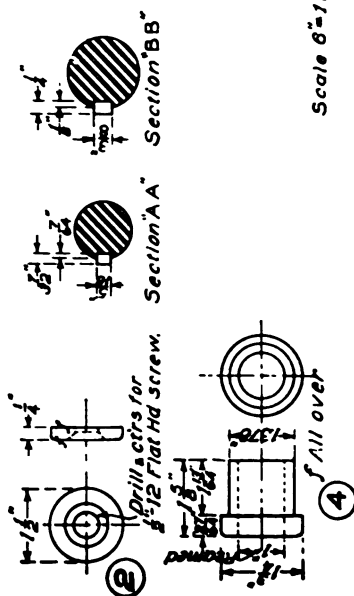
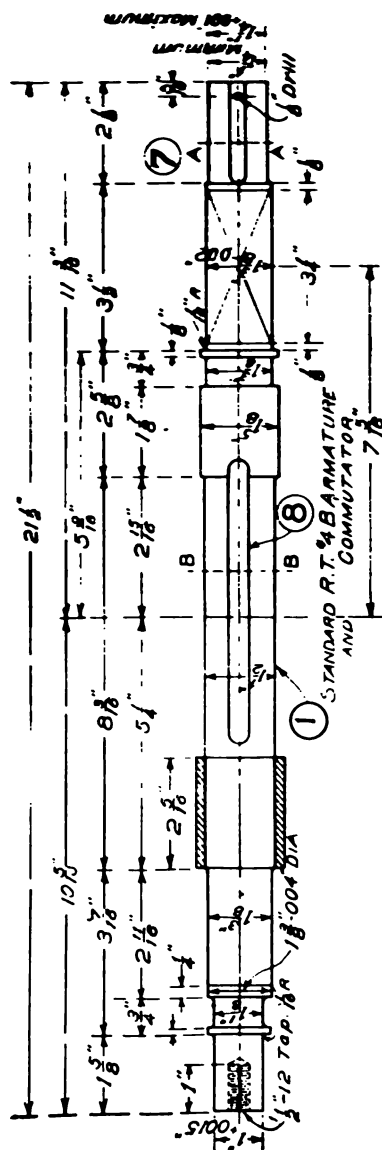
CHICAGO, ILL.

FOUR INCH PILLOW BLOCK

Open Half Size







TYPICAL WORKING DRAWING OF ARMATURE-SHAFT MADE IN THE DRAFTING ROOM OF THE SPRAGUE ELECTRIC CO

PLATES.

PLATE VIII.

Pipe Coupling. The drawing represents one of a pair of cast-iron couplings used for connecting two lengths of pipe. It is threaded for a right-handed thread, but appears left-handed because the back part of the thread is visible in the section.

The vertical center line of the coupling is in the center of the plate; the center of the plan is $3\frac{7}{8}$ inches from the lower border and the bottom of the elevation $1\frac{7}{8}$ inches from the top border line. The elevation is made in half section, that is, the right-hand half. It is made by imagining that the front right quarter of the coupling is cut away by vertical planes. If the cutting plane passes through a hole or opening the cross-hatching is omitted. The dotted lines at the left of the hole show that it is threaded. The distance between these lines is $\frac{3}{32}$ inch, the depth of the thread. The threaded or tapped portion is shown in plan by the two circles, the dotted circle representing the outside and the full circle the inside or root of the thread.

The boss or hub adds to the strength and allows more threads. The shade lines should be placed on the drawing following the custom for shop drawings. The title "Pipe Coupling" should be placed as shown and made with letters $\frac{1}{4}$ inch high. The letters may be either vertical or inclined Gothic capitals.

PLATE IX.

Pillow Block. The drawings for this plate are three views—side, plan and end—of a 4 inch-pillow block. Each view is half in section. The drawing should be one-half size. Make the vertical center line of the side and plan views $4\frac{3}{4}$ inches from the left-hand border. The horizontal center line of the side view should be $2\frac{3}{8}$ inches from the top border line and the horizontal center line of the plan $2\frac{1}{4}$ inches from the bottom border line. Locate the vertical center line of the end view $2\frac{1}{4}$ inches from the right-hand border line; the horizontal center line will of course be a continuation of that of the side view. Note that the left-hand half of the plan represents what is seen by looking up from below. The cutting plane for the right-hand half passes horizontally through the center of the shaft.

The student should put on shade lines and finish marks: also the axes and dimensions. Make the letters of the title vertical. *Write capital 3 inch high.*



Fig. 48.

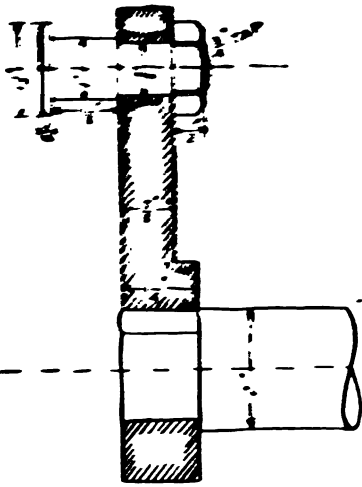


Fig. 49.

PLATE X.

Overhung Crank. The two drawings on this plate are to be made full size from the free-hand sketches Figs. 48 and 49. These are such as would be given the draftsman or such he would make for his own work. Place the two views so that they will look well on the plate. Put on shade lines and dimensions.

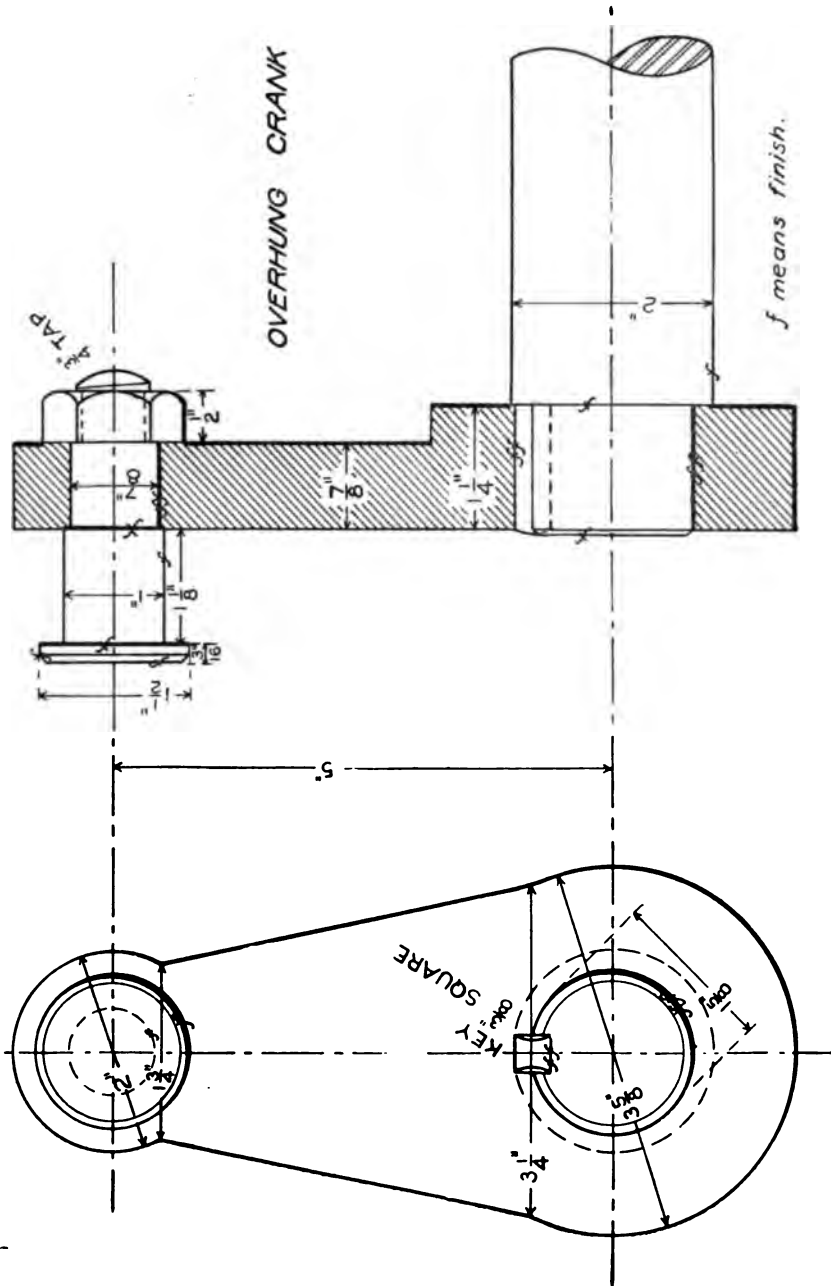
PLATE XI.

Cylinder Head. This plate consists of a plan view and a cross-section of the cylinder head of a small engine. The center line for the two views is drawn half way between the upper and lower border lines. Always allow sufficient space for dimensions.

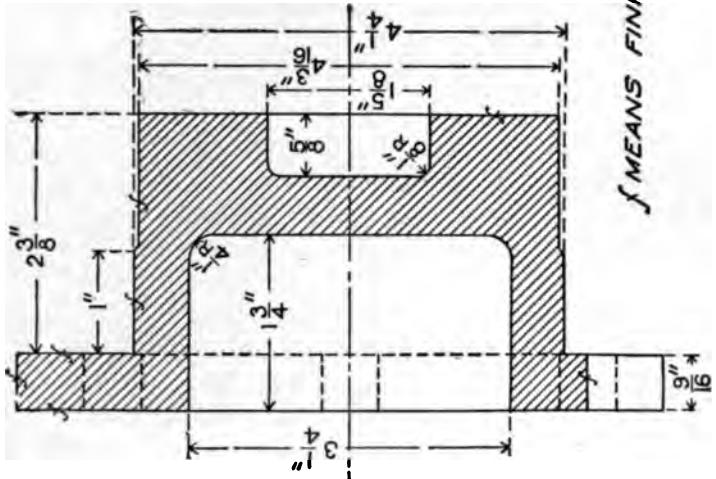
The shade lines should be placed on the drawing, following the methods described for machine drawing. Locate the title and explanatory notes to make the plate appear well balanced.

PLATE XI A.

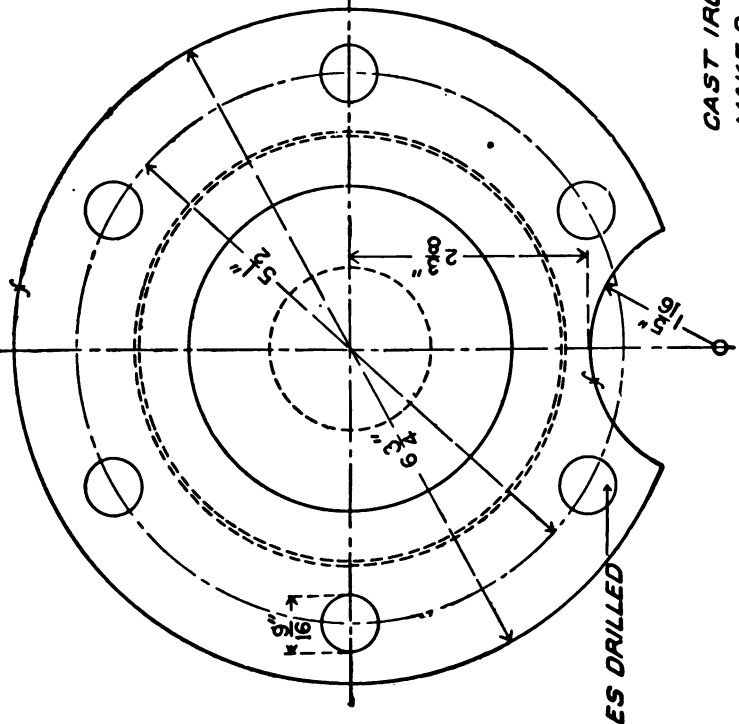
Blue Print. Make a tracing on tracing cloth and (optional) a blue print of one of these plates.



1



f MEANS FINISH



CAST IRON
MAKE 2

HOLES DRILLED

MECHANICAL DRAWING.

PART VI.

WORKING SHOP DRAWINGS.

In Parts I to IV, inclusive, the fundamental principles of Mechanical Drawing were explained and illustrated. The production of working drawings has also been discussed to some extent, and the usual characters and symbols explained and applied. The elementary work already outlined has been treated chiefly from the standpoint of correctness of line representation considered by itself, without a detailed study of the use to which the drawings so produced are to be applied.

Evidently this is the proper method, for the student should gain a thorough understanding of the principles which underlie line representation before attempting to apply them to any extended practical use. In all of this preceding work it is intended that the theoretical principles shall overshadow any incidental references made to practical application, however true and pertinent the latter may be for purposes of illustration. Hence, before taking up any advanced work, the student should fully realize the importance, in fact, the absolute necessity, of thoroughly understanding the fundamental principles which have been outlined in the books which have preceded Part VI.

At this point the student must realize that a lack of proper elementary and fundamental training will make him "go lame" at every point of his course, and probably prevent the attainment of proficiency which otherwise would naturally and almost instinctively come with advanced study. It is the thorough and ready knowledge, always at his fingers' ends, of *all* the principles of Mechanical Drawing, which makes the expert draftsman.

Plan and Scope of Advanced Work. It is now intended to throw an entirely different light on the matter, and view the subject of Mechanical Drawing from a purely practical standpoint; viz., that of Utility. It is assumed that the student

understands and can use the principles which have been previously discussed.

If in a working shop drawing we choose to modify any of these theoretical principles, it will be because of increased value in *Utility* of the drawing. For example, we may desire to omit some portions of an elevation or plan or side view of a complicated casting, because certain details will thus be more clearly brought out. We may make a "zigzag" section to show construction which, by absolute fidelity to theoretical principle, would be confused, or hidden in a maze of dotted lines. We may find it convenient to place in some unoccupied corner of a drawing a layout which could not be in the least justified by any rule of projection. A multitude of transgressions like these occur on good drawings, and they are certainly justifiable from the standpoint of *Utility*, which is the true ultimate end sought for in a practical shop drawing.

These variations from the theoretical are not strictly conventionalities, because they are not classified or established, so far as we know, but are the spontaneous outgrowth, as the occasion demands, of the draftsman's purpose to make his drawing one of greatest *Utility*. He can, however, safely transgress a principle only when he thoroughly knows the principle; otherwise a blind deviation from the theoretical path will inevitably lead to difficulty.

All of the above is intended to impress the student with the idea that theoretical principles are his best, in fact, his only tools to work with: but they are not "self-hardening," like "mushet" steel; they are like the finest grade of tool steel, which must be tempered and ground and used with the best judgment of the operator, to secure the most satisfactory results.

Student Drawings. A student's early drawings are usually unsatisfactory, even to himself. Somehow they do not look like those seen in shops, and as a rule he is unable to see why this is so. Of course the difference is to some extent due to the experience of the professional draftsman. However, the superior results of the latter's work are attained largely through his systematic and workmanlike habits of execution. It should encourage the student in his early attempts to know that these essentials to

the infusion of life and shop spirit into a drawing can be analyzed, outlined and grasped at the outset by earnest, intelligent effort, and really good workmanlike results obtained. To discuss, and if possible to impart these essentials of a working shop drawing to the student, is the purpose of the present book.

Essentials. The two chief essentials of a shop drawing, under which general heads a multitude of detail requirements can be summed up, are:

(1.) Absolutely complete and definite instructions from designer to workman.

(2.) Least possible cost in dollars and cents of production of the drawing measured by the draftsman's time.

It makes no difference how much we may attempt to disguise these two elements, the fact will still be apparent that "*complete instructions furnished for the least money*" is what the manufacturing shop is after, and what will be assumed as a basis for judgment as to highest commercial utility.

Completeness of Drawings. As to the first point, that of completeness and definiteness of instruction, there must be no question of degree. If the information which the drawing furnishes is positive and complete, the drawing is good. If doubt arises in the workman's mind as to what the designer intended by a certain line or dimension, or if the dimension be omitted, the drawing is bad. There is no middle ground. The instructions are either present or absent, and the drawing good or bad accordingly.

The workman of to-day is not permitted to assume dimensions or shape. It is his business to execute the draftsman's orders; it is, however, often his privilege to choose his own way of doing it, but further than this modern practice does not allow him to go. He is held as rigidly to the orders specified by the drawing as the locomotive engineer is held to his bit of tissue telegraphic order to proceed, without which he dare not enter the next block. The drawing is supreme; it is official; it must be plain, direct and all-sufficient. It is the draftsman's business to make it thus, and he is not a draftsman until he does.

This idea of positiveness must be thoroughly absorbed by the student. Positive action must be a habit which controls his every

move, which marks every dimension he prints, which directs every line he draws. Every line must mean something, must have a definite reason for existence, must be necessary to illustrate the idea which he wishes to convey to the workman, and every line must be a definite measurable distance from every other line, so that its location is fixed beyond a doubt. Lines which mean nothing, and cannot be measured, have no place on the drawing; they only confuse it.

A good picture of a machine could scarcely be called to the same service as a good drawing of it. The picture might give us an excellent idea of the machine, but for the purpose of the actual construction the picture is useless, while the drawing is of positive value. This value exists simply because of, and in proportion to, the completeness of detail which it shows. Hence in making a shop drawing the picture idea is entirely subordinate to the idea of *Utility*, the latter in fact being the measure of its value.

There are certain classes of drawings—of which the Patent Office drawing is a good example—in the making of which the picture idea is predominant. Here the purpose is to illustrate mechanisms, not construct them; hence the function of the drawing is in no wise that of the working shop drawing, and as such does not fall within our discussion.

Cost of Producing Drawings. The second general element involved in producing shop drawings is their cost, as measured by the draftsman's time. It is somewhat subordinate to the first element, for the drawing must be a good one, judged by an absolute standard, whatever the time or cost necessary to produce it. Cost, however, is an important item, and cannot well be overlooked. It is inevitable that in any enterprise economy will ultimately be sought, whatever extravagance an imperative original demand may have permitted. This is as true in the production of drawings as in the case of manufactured articles of trade. Drafting-room labor is a relatively high-priced service, and the salary list easily assumes considerable proportions, so that wasteful excesses count up rapidly. One of the qualifications of proficiency invariably required for this department of shop organization is rapidity of execution. This is not as dependent upon personal traits as at first might be supposed. A man may so husband his time and

direct his efforts that he will easily distance his neighbor of more rapid motion. The latter may have less ability to make his energies count, and lack of judgment as to when just enough, and no more than enough, energy has been expended on his drawings. From the standpoint of *Utility*, the function of a drawing is fulfilled when it has reached the stage that it *completely* instructs; more time spent in elaboration is wasted, and is an unnecessary and therefore extravagant expenditure. The student must fully realize this. In his earnestness to produce finished and complete work he must constantly strive to accomplish results in the least possible time. This does not mean careless haste; far from it. A complete shop drawing cannot be made by short cuts, but through a systematic building of line on line, dimension on dimension. This is in sharp contrast to a haphazard habit of developing a drawing, first a line here and then a figure there, with no definite purpose in mind, and no hint as to when the drawing is actually completed.

The one method constitutes the efficient draftsman who works easily, receives a high salary, and is worth it, because he wastes no time in unnecessary labor. The other marks his unfortunate brother, plodding laboriously far behind, receiving a small pittance per hour, and worth less, because he does uncalled-for labor, and loses his definiteness of purpose in a maze of unexplainable lines and figures.

A working shop drawing, commercially considered, may well be defined as being “*Complete instruction from designer to workman issued at minimum expense.*”

This definition should be memorized by the student, and constantly kept in mind while making a drawing. The preceding pages should be re-read with this in view until the full spirit is appreciated.

The maxim as given above, if faithfully adhered to without modification, answers nearly every question that can be raised as to the excellence of a drawing. It can be used as a standard of judgment, whatever system of lines or symbols may be in vogue. It permits a draftsman to adjust himself to the rules of any shop or drawing-room, and yet produce a good drawing and satisfy his employer.

A drawing which is cheaply produced and at the same time does perfectly that for which it was made, that is, convey complete instruction, is beyond commercial criticism.

Method of Procedure. As the general objects to be attained in a working shop drawing have now been presented, it is necessary to indicate in detail how the work may be properly accomplished. In order to do this, it is proposed to produce systematically a full set of working drawings of a familiar and comparatively simple machine. The methods used will be those of a designing detail draftsman, producing commercial work fit for shop use. In the progress of the work, from its beginning in the rough, though accurate, pencil layout, to the completion of the tracings and the order sheets, the same bold style, clearness, directness and businesslike spirit which the shop atmosphere and surroundings would naturally supply, will be emphasized, and so far as possible imparted to the student. It is expected that the student will follow the text closely and study the plates carefully, endeavoring to familiarize himself with every detail illustrated. The more closely he is able to apply himself in this respect the more will he be able to partake of the life and spirit which is intended to be conveyed, and without which the true character of the work can be but poorly developed.

Incidentally, several purposes will be fulfilled by this treatment.

Ability to read drawings quickly and intelligently is almost as important as making them, and it is expected that the study of the plates, with a view to thoroughly understanding every line, will develop proficiency in the art of reading drawings.

The discussion in the text, of not only the form of the machine parts themselves, but also the tools and shop processes to produce them, affords considerable insight into the influences affecting good machine design. Without introducing any mathematical analysis or investigation, which is beyond the province of this book, much practical consideration as to the restrictions imposed by existing shop methods upon theoretical construction will be suggested, and the student encouraged to use his judgment thereon.

In the preliminary layouts the actual "sketchy" appearance

of the pencil drawing will be imitated as far as possible, so that the student himself may imitate and catch the bold dash, yet fine accuracy, of the line-work, which is characteristic of the expert draftsman.

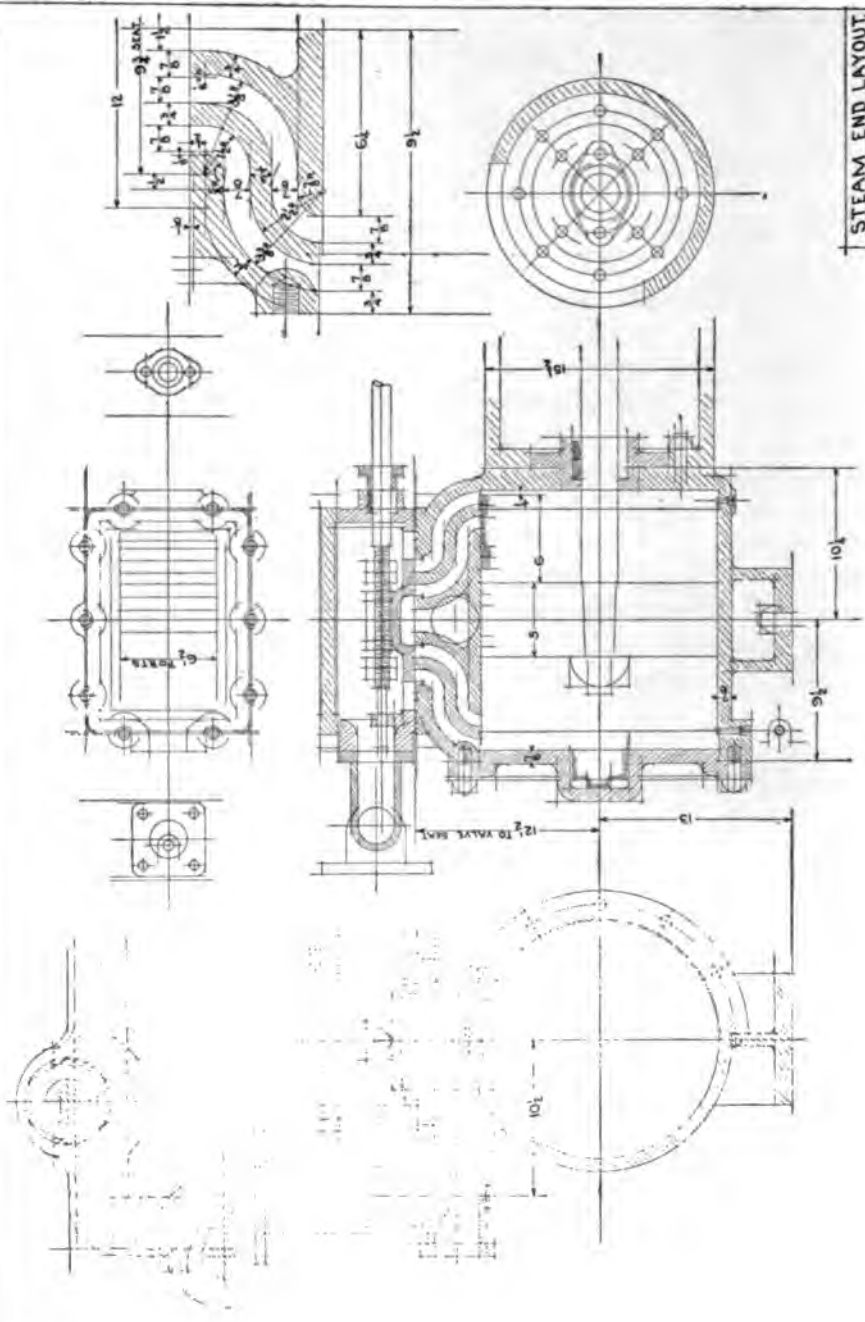
The completeness of a *set* of drawings is as important a lesson as the completeness of each drawing itself. In this is involved the proper arrangement and classification of details, the foundation layout, and the system of order sheets for getting work into and through the shops. This is a feature which very strongly affects some of the finishing touches to a drawing, for it is so easy to omit a "few last things" and turn in an uncompleted sheet. Every draftsman knows how many little things come up toward the close of a job involving complete drawings of a machine, and how strong the tendency is to omit them, and relieve himself of somewhat tedious details. The result is irritation and delay when the drawings get into the shop, and they return to the drawing room to be fixed up at a time probably inconvenient for all parties concerned. A good draftsman will turn in a *complete* set of *complete* drawings. It is highly important that the student grasp this idea, and study his work accordingly.

DUPLEX PUMP PLATES.

The typical set of plates chosen for this book in fulfillment of the above purposes, takes up the study of a simple, duplex steam pump. This particular type of machine represents the simplest and most elementary form of the steam engine in modern use in respect to valve gear and controlling devices. It is not an economical machine, yet its principles lie at the foundation of the economical high-speed engine, the latter being produced through a modification of the uneconomical valve gear such as is found on a pump of the type chosen, rather than through any radical change of construction as to the body of the machine. Hence the study of a steam pump may well precede that of higher forms of the steam engine. It is hoped that the study will so interest the student that he will be led to further investigation and development not only of the steam engine itself, but of that highly important division of modern engineering,—pumping machinery.

Thus we note another point of advantage in the study as out-

STEAM END LAYOUT
 16-81-12 DUPLEX PUMP
 AMERICAN SCHOOL OF
 CORRESPONDENCE
 CHICAGO - ILLINOIS
 SCALE 3/4"



lined. The power end of the machine introduces us to the steam engine; the load end is the beginning of the engineering of pumping machinery.

Rating of Pump. A steam pump is rated by the bore of its cylinders and length of stroke, all being given in inches. A "16 $\times$ 8 $\frac{1}{2}$ $\times$ 12 pump" means that the steam cylinder is 16 inches in diameter, the water plunger 8 $\frac{1}{2}$ inches in diameter, and the nominal length of stroke 12 inches. These sizes are always given in the same order, beginning with the diameter of the smallest cylinder (in case there is more than one), then the diameter of water plunger, the common stroke of both being placed last. This expresses to the mechanic the rating of the pump in the clearest style and briefest language.

The pump illustrated here is designed for standard service, operating under a steam pressure not to exceed 100 pounds per square inch, water pressure not to exceed 150 pounds per square inch, and the rated capacity based on an average piston speed of 100 feet per minute being about 550 gallons. This requires that each side of the pump shall handle 275 gallons, and being double acting, shall make 100 reversals or 50 double strokes per minute.

Plate A. Steam End Layout. This plate illustrates, as nearly as reproduction can accomplish, the pencil layout of the steam end. It is the first work of the designing draftsman. The drawing as shown is exactly the type of layout which he would turn over to a detail draftsman, whose duty it would be to work up detail shop drawings therefrom.

The character of this drawing should be carefully studied. Remember that it is a layout, nothing more; also bear in mind that it is an exact, measurable working sketch. Attention is called to the sharpness of the lines, especially to the clean-cut intersections. Note the boldness, dash and businesslike style, the free-hand cross-section lines roughly put in. There is no hesitation or worry as to where the end of a line shall be, or whether it crosses other lines which it theoretically should not. The intersections are allowed to indicate the termination of lines, and the rough section lines pick out the parts and separate them clearly to the eye. There is the spirit in this layout of confident, definite and rapid action, with no thought for absolute finish in line-work, but

with every thought for absolute results as to measurable dimensions.

The data for the production of Plate A by the student are rather more complete than he would usually find in practice. Plates E, F and G show many details fully.

The steam cylinder and head, however, as shown in Plate G, are not dimensioned, and the student's problem is to produce this plate complete, with finish marks, dimensions and necessary data for a working drawing. In order to do this it is first necessary to work up Plate A with exactness, in pencil, and see that all parts go together properly. Then the detail of cylinder and head may be made separately by measurement of the layout drawing, and Plate G produced.

For this work the ordinary brown detail paper is very satisfactory. A hard lead pencil is necessary, as hard as 6H, and the point must be kept well sharpened.

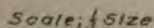
There are two general rules of action in producing a drawing which give the answer to the question which oftenest confronts the beginner: "What is to be done first?" or "What is to be done next?" These rules are:

1. Draw everything that is positively known.
2. Work from the inside to the outside.

Every problem has some positive data, assumed or calculated, to start with. The first thing to do in every case is to get this data represented by lines on the paper. An expert designer has been heard to say that until he had spoiled the blankness of his sheet of paper by some lines, he could not design. There is something in this; and almost invariably the first line to draw is a horizontal center line somewhere near the middle of the sheet; draw it! Draw it at once without hesitation, and the layout is begun. We now have something about which to build.

In this case the designer would first calculate the size of the piston rod, and determine the fastening to the piston. He would then draw the rod and build a hub around it. He would next calculate the width or thickness of piston and size of packing rings, and draw the two vertical lines 5 inches apart, to indicate the piston faces. These lines would be limited by the cylinder bore, which he knows to be 16 inches; hence horizontal lines 16

CINCINNATI, O. U. S. A.



9983-1 1-3-1902 ①Changed from 1 1/2" length over all, also changed to suit 9983	9983-2 4-1-1902 ②Changed from N27 to N26 taper pin A.B.V.	9983-3 4-1-1902 SHAFT AND ASSEMBLY OF DRUMS TYPE F. CONTROLLER.	Material.....No. Reg'd..... Tool No..... Pat. No..... Est. Weight..... Draftsman A.B.W.
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EXAMPLE OF SHOP DRAWING REPRODUCED FROM A BLUE PRINT BY THE COURTESY
OF THE BULLOCK ELECTRIC MFG. CO.

1

inches apart, parallel to and symmetrical with the center line, are the next to be drawn. Short vertical lines indicate the location of the packing rings. As the nominal travel of the piston is to be 12 inches, the location of the piston and rings can be shown on both sides of the central vertical line at the limits of travel. A clearance must exist between the heads and the piston (in this case $\frac{1}{4}$ inch is allowed), hence the lines of the heads can be drawn, and the general inside outline of the cylinder barrel is complete.

This is all in direct application of the foregoing rules, and is so simple, natural and direct that it hardly requires such explicit statement. We have simply taken such data as we had and put it on paper, placing it where it can be seen from all sides, and where the mind is relieved of the labor of carrying it.

If the student will only appreciate this one rule and draw all he knows about the problem, he is well on his way to its solution. *Draw everything you know, and work for what you don't know*, is what these two rules say, and the first question to arise should be: "Have I drawn everything that is known about the problem?" before he asks himself or any one else: "What shall I do next?"

One other rule might be added to these two: *Keep dimensions in even figures, if possible*. This means that small fractions should be avoided. It is just as easy to bear this point in mind, and save the workman much annoyance and chance of error, as it is to disregard this matter. Even figures constitute one of the trade-marks of an expert draftsman. Of course a few small fractions, and sometimes decimals, will be necessary. Remember, however, that fractions must in every case be according to the common scale; that is, in sixteenths, thirty-seconds, sixty-fourths, etc.; never in thirds, fifths, sevenths, or such as do not occur on the common machinist's scale.

A systematic, definite mode of treatment on these lines must become a habit, so that all problems, however complicated, can be approached with confidence in the same way. It is the drawing of one line which makes clear the drawing of the next and subsequent lines; and the most serious obstacle which the student is likely to set for himself is trying to see the whole problem through from the beginning. Even an expert cannot do this, but allows the layout to develop results as he proceeds.

The details of the piston and rod being given in Plate E, the foregoing work is very easy for the student. The thickness of the barrel and heads being determined ($\frac{7}{8}$ inch in this case), the exterior outline may be partially drawn. The fixed head at the yoke end must be thicker than this, in order to receive the yoke and stuffing-box bolts without breaking through. The recesses or counterbores at either end of the cylinder should be so located that the packing rings run over the edge a little at the end of the stroke, thus preventing the wearing of a shoulder by the piston stopping in the same place every time. The counterbore should be deep enough to allow reboring the cylinder without the counterbore being touched by the tool. In this way the counterbore is retained to center the cylinder at its original location.

The size of steam ports having been calculated, they may be drawn in, the turns being made easy and as direct as possible. The height to valve seat must be kept at the lowest limit consistent with sufficient metal between and outside of the ports. As the detail of the ports might be somewhat troublesome, it is shown in an enlarged sketch for the student's benefit. Chipping or filing strips $\frac{1}{8}$ inch high are left on the port edges, which must be true, in order to finish them up easily.

The three inner ports are for exhaust, the outer ones for admission of steam. This five-ported cylinder is peculiar to the direct acting steam pump, it being a device to effect the cushioning of the piston at the end of the stroke, thus preventing the piston from striking the heads. This is necessary, since no positive limit of motion exists, as is the case in machines with crank and connecting rod.

When the edge of the piston has passed the outer edge of the exhaust port, as shown in Fig. 1, the steam, which has been exhausting through port A, is confined in space B and port C, and, being compressed by the piston, acts like a spring to retard its motion. If the point P is properly determined for a given speed, the piston will always compress the steam just enough to cause it to stop at the end of the nominal stroke; in this case, $\frac{1}{4}$ inch from the head. It is evident, however, that at different speeds the piston will have more or less power to compress the steam, and will not stop at the point desired. This causes the trouble of "short stroke," and

consequent inability to make the pump work to its full capacity. Now if we connect ports A and C by a small opening shown dotted at D, and control this opening by a plug valve operated by hand from the outside, we can let a little steam leak by into port A, thus reducing the cushion and allowing full stroke.

In order to avoid complicating the drawing, no cushion valves are shown or required to be put on by the student. They are not customary in small pumps, but might advantageously be put on the present illustration.

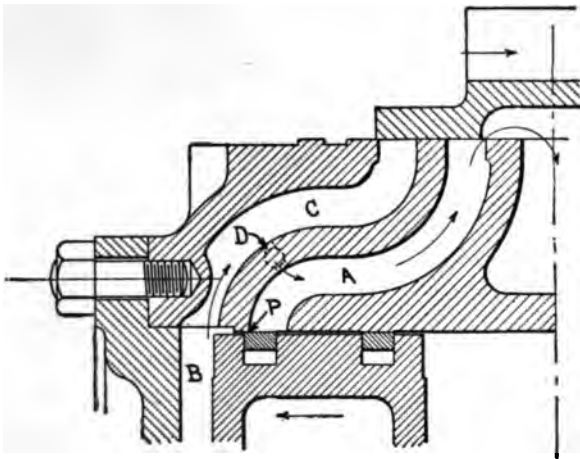


Fig. 1.

The valve seat must be a scraped surface, while the chest face need not be; hence the latter is finished $\frac{1}{8}$ inch lower. This also gives a ledge against which the steam chest fits, thus securing positive location.

The bolting of the heads and the steam chest should allow a width of packing inside of the bolts of $\frac{1}{2}$ to $\frac{5}{8}$ inch, otherwise there is danger of the steam blowing out the packing and causing leakage around the bolts. The bolts do not fill the holes, the latter being drilled large, from $\frac{1}{4}$ to $\frac{1}{2}$ inch. The spacing, if wider than 5 or 6 inches, is likely to permit springing of the flanges between the bolts, and consequent leakage. Bolts less than $\frac{5}{8}$ inch diameter are not desirable, as they can be easily twisted off with an

ordinary wrench. In this case the cylinder head takes $\frac{1}{8}$ -inch bolts, the yoke, stuffing-box and gland, $\frac{3}{4}$ -inch.

The flanges of heads and cylinders are usually from 25 per cent to 50 per cent thicker than the body of the casting.

Drips, $\frac{1}{2}$ -inch pipe tap, to be fitted with cocks, are necessary at both ends of the cylinder to readily drain the cylinder of water.

Molding of Steam Cylinder. The design is often influenced by the way in which the piece is to be cast. It often takes but a slight change of design to save many dollars in pattern making and foundry work. Hence the habit should be formed of always judging the design of a piece from the foundry standpoint. In this case it is evident that the ports and cylinder bore must be cored out, and the most obvious position of molding is to lay the cylinder on its side, the parting line of the flask being along a vertical plane running lengthwise through the middle of the cylinder. This permits the chest flanges to draw nicely, likewise the ribs on the foot, and allows the thin curving port cores to stand edgewise in the mold.

Another method of molding would be with the valve seat down. This would involve loose pieces for the chest flanges, and setting of cores for the cylinder foot. It would, however, assure sound metal beyond question at the valve seat. Spongy metal at the important wearing surfaces, the valve seat and cylinder bore, is not permissible in any case, and care in molding, and good design, is necessary for good results.

All corners must be carefully filleted, and chunks of metal must be avoided, especially where several walls or ribs join. The metal must be kept of average uniform thickness, so that the whole casting will cool uniformly.

Machining of Steam Cylinder. The boring may be done on a vertical boring mill, the heavy arm carrying the tool being thrust down unsupported into the cylinder, the latter being rotated by the table to which it is clamped. If the horizontal boring machine be used, the hole through the inside head for the stuffing box must be large enough to permit a stiff boring bar to be passed through. This allows a support at each end of the bar, to take the strain of the cut.

The plane surfaces may be finished on a reciprocating planer

or a rotary planer. In the latter case it is desirable to keep all lugs or projections back from finished surfaces, to permit the large round head which carries the cutters to pass over them without interference.

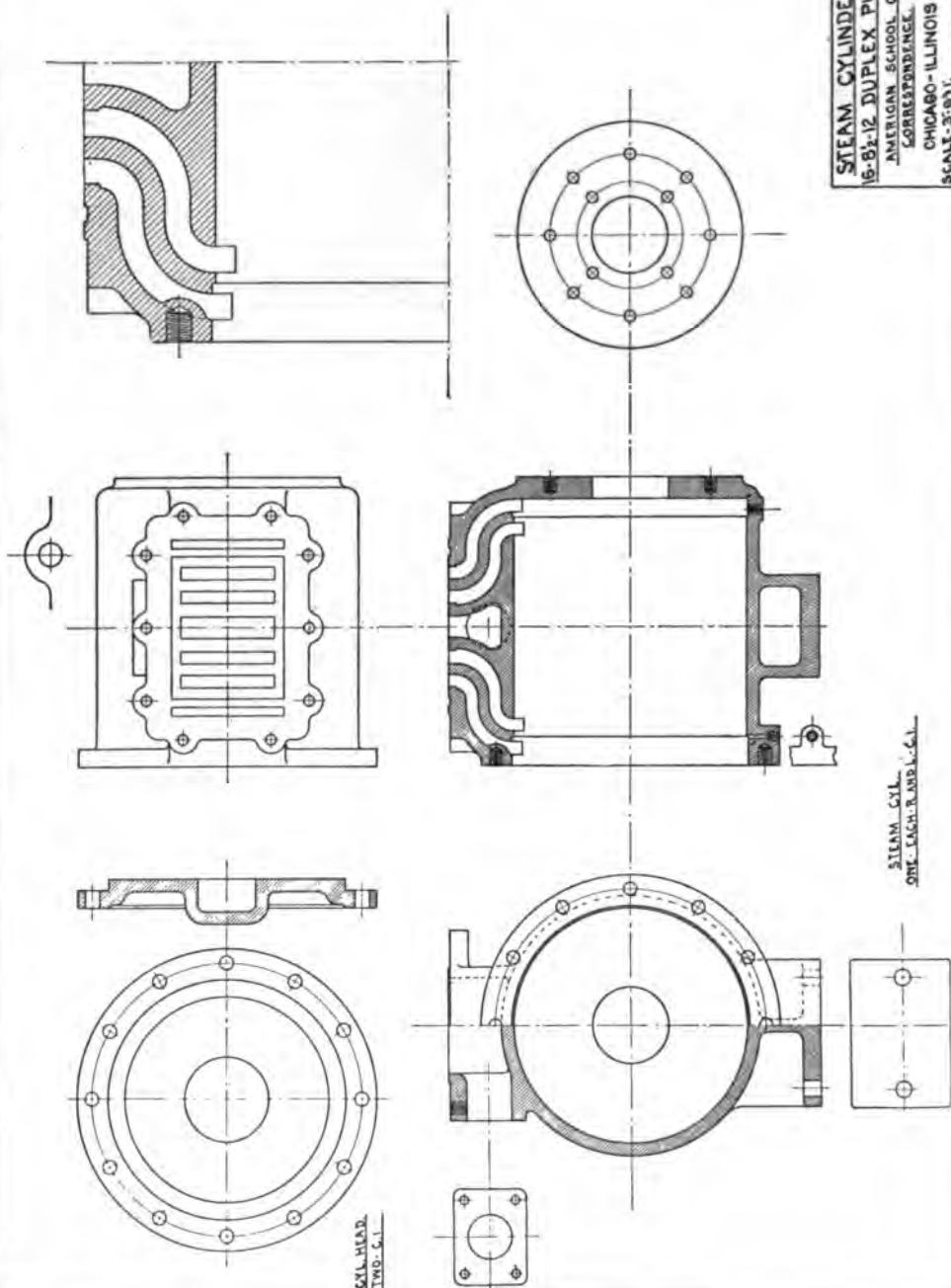
The drilling of standard machine parts of this character is usually done through jigs, or plates carrying hardened steel bushings laid out to correspond with the holes required, and through which the drill is guided. These plates are located by some fixed line or lug on the casting, and then clamped fast, thus assuring exact duplication and rapid drilling, and avoiding the tedious laying out of the holes. In order to save changing the drill it is desirable, if possible, to maintain the same size of hole on any given surface. Of course it is not always admissible to do this.

Plate G. Steam Cylinder. After the exact and complete development of the steam-end layout, the student should be pretty thoroughly acquainted with the details of the cylinder. All the work thus far has been entirely for *his own* information, to get his ideas in visible shape, so that he himself can have a permanent record of them. This layout, however, is not in suitable form to finish up into a detail drawing. Its sketchy nature and the confusion of parts, especially if attempt were made to add dimensions, would render it somewhat difficult to be read by a workman taking it up as an unfamiliar subject. Hence it is now necessary to separately detail the parts, with the object in view of transferring, in the simplest and most direct manner, specific information to the workman which will enable him to construct the several parts. It is not enough now that the drawing be clear to the man who makes it; it must be clear, *absolutely clear*, to the shop mechanic, who has no means of knowing the designer's plans except through the information which the drawing gives on its face.

This requires that the draftsman should put himself in the workman's place, and forestall, by the explicit nature of his drawing, all possible questions which may arise in the shop. In this way only can he hope to avoid errors of construction and the continual annoyance of endless explanation of his orders.

Plate G is to be a finished drawing, and the first thing to do is to lay out the sheet. The standard sheet for details which has

STEAM CYLINDER.
16-82-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE.
CHICAGO-ILLINOIS
SCALE-3/8"=1".

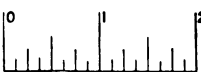


CYL. HEAD.
TWO-6.1.

STEAM CYL.
ONE EACH TWO-6.1.

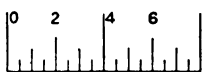
been adopted is 18×24 inches trimming size, with $\frac{1}{2}$ inch margin all round, so that the working space is 17×23 inches. The rectangle for the title is to be laid off $2\frac{1}{2} \times 4$ inches in the lower right-hand corner, and must never be altered, either in size or position. This does not mean that other sizes are wrong, but once a standard system is adopted it must be strictly adhered to, both for artistic and commercial reasons. The scale to which the drawing is to be made is indicated in the title corner on every plate.

The scales permissible for shop drawings in the United States are those readily derived from the common foot rule, such as full size, 6 inches = 1 foot, 3 inches = 1 foot, $1\frac{1}{2}$ inches = 1 foot. These are the most common, most easily read from an ordinary scale, and one of these can usually be adopted. The student should learn to read these from an ordinary scale without being confined to a special graduation. To do this it is not necessary to divide each dimension by 2, 4 and 8 to get half size, quarter size, or eighth size, and then lay down the result. For half size, or 6 inches = 1 foot, $\frac{1}{2}$ inch on an ordinary rule represents 1 inch. Hence, each half inch may be read as 1 inch, and

its subdivisions accordingly, thus:  For 3 inches

= 1 foot, or quarter size, $\frac{1}{4}$ inch represents 1 inch, and looks

thus:  For $1\frac{1}{2}$ inches = 1 foot, or eighth size,

$\frac{1}{8}$ inch represents 1 foot, and looks thus:  It

is very easy to get accustomed to this, and it saves much time and trouble hunting up a special scale every time.

The other allowable scales, less common, but sometimes necessary on large work, are 1 inch = 1 foot, $\frac{3}{4}$ inch = 1 foot, $\frac{1}{2}$ inch = 1 foot, $\frac{3}{8}$ inch = 1 foot, $\frac{1}{4}$ inch = 1 foot, and $\frac{1}{8}$ inch = 1 foot. To use these scales conveniently, special graduation is desirable.

The general arrangement of the sheet, number of views and approximate space occupied, should be blocked out first. This can easily be done from the original layout. In general, several cross-

sections are preferable to a single view, which involves many dotted lines. Dotted lines are very convenient for showing invisible parts of an object, but they are often abused, and the drawing of a complicated piece made indefinite and confused thereby. As already stated, a working shop drawing is solely to convey information to the workman at the least possible cost. A careful consideration of this will settle the question of the number of views necessary, their character, and the amount of dotted line work desirable.

Never let the drawing become the master; always be master of the drawing. Do not draw an extra view if no use can be seen for it. Do not put in dotted lines if the detail is completely shown without them. Full lines, or lines which show visible portions must, of course, be shown completely.

The nature of the pencil work on Plate G should be the same as on the original layout; viz., sharp, definite lines and positive intersections. Above all things learn the habit of accurate workmanship, for it will save many errors and a vast amount of time. The draftsman must check himself at every line he draws. Slight errors in scaling will often throw parts out of proper relation to each other, and interferences, which the drawing does not show, will become apparent only when the parts get into the machinist's hands.

It is dangerous practice to project across from one view to the other. It only takes a slight irregularity or spring in the T-square to vary the location of lines very perceptibly from where they should be, and once out of scale from this reason it is almost impossible to work a view with any certainty. Rather than project across from view to view, the principal lines, at least, should be scaled off on each view, and it will be found that in the end time will be saved and greater accuracy secured.

It is not economical of time to finish one view before beginning another. It is better to take some single detail of the drawing and develop it in all views, in order to study it from all sides. What is completed in one view may be found to be totally wrong when developed from another side; and the time spent on the first view will be wholly wasted. For example, in the present case the steam ports should be drawn in side elevation, end eleva-

tion and plan, and when thus completed the mind can leave them and in a similar fashion take up the study of the flanges, then the cylinder foot, and so on. Thus again the draftsman is master of his drawing, for he is continually making it tell him whether he is right or wrong. If, on the contrary, he allows himself to look at but one side at a time, and works from that standpoint alone, it may lead him into many difficulties from which he cannot readily extricate himself.

Do not be afraid to use the eraser. The draftsman who hesitates to draw until he is positive that no change will be necessary, is likely to spend the greater portion of his time in unprofitable dreams, for he is attempting the impossible. A drawing is a means, not an end; and, as has been already pointed out, it greatly assists the draftsman in clearing up many doubtful questions which the imagination alone cannot do.

A bold attack of a problem shows the quickest path to its solution, even if lines must be erased again and again. It is a sign of serious lack of ability to hesitate in the use of pencil and eraser.

Attention is called to the simple, straightforward character of Plate G. Notice the almost entire absence of dotted lines; the enlarged section through the ports, giving ample opportunity for dimensions without confusion; the use of a half end elevation and a half cross-section,—the one to make clear the flange and bolt layout; the other to show the exhaust opening, the small auxiliary views (drawn at convenient points) of the exhaust flange layout, the cylinder foot and the drip boss.

A steam cylinder is a fairly complicated casting; and it would be an easy matter, by the use of elaborate views, the dotting in of parts already completely shown, and careless line work, to rob this drawing almost entirely of its clearness and directness of illustration. *Just what is necessary* (for clearness' sake) *and no more* (for cheapness' sake), is the whole matter in a nutshell, and is what determines its shop and commercial value.

Dimensions and Letters. A good line drawing can be spoiled by poorly arranged dimensions and hasty lettering. The five principal points to be kept in mind to develop excellence in this respect are:

- (1) System.
- (2) Accuracy.
- (3) Clearness.
- (4) Completeness.
- (5) Character.

System. The habit of system in placing figures and letters on a drawing is the one element which, to a large extent, controls all the others. If the systematic habit is established early, the other requirements will be fulfilled more easily. A haphazard method will, on the contrary, just as surely prevent the successful cultivation of the ability to figure a drawing. In fact, if the haphazard habit is continued it will itself, by the dissatisfaction which it causes, soon compel the draftsman to change his occupation.

In the first place, whatever part of a machine detail is to be dimensioned, that particular part should receive attention until it has been completely figured. Do not jump from one point to another, putting in a figure here and another there. Stick to one thing until it is done.

For example, take Plate F and the simple detail of the steam pipe. Suppose we start with one of the square flanges. The first question is: "Where is this flange located?" This is answered by the dimensions 5 inches and 21-inch centers, which refer the face of the flange to the center of the pipe and the flanges to each other. The next question is: "What are the three dimensions of the flange,—length, breadth and thickness?" This is readily answered as shown on the drawing. The next question is: "What further description is necessary to completely specify the shape of the flange?" This is answered by the radius of the corners, $\frac{3}{4}$ inch R. Next, "What drilling or special feature exists in the flange?" This is answered by $1\frac{1}{16}$ -inch drill, $3\frac{1}{2}$ -inch centers, and the letter *f* to denote that the face is to be finished.

The round flange of this pipe is approached and figured in the same way, except that the location of the face is preferably referred to the face of the square flange by the figure $8\frac{1}{4}$ inches, instead of to the center of the pipe, because the planer hand will more naturally use this figure.

These flanges are now to be connected by a pipe involving two sizes. The main pipe is 3 inches diameter inside, 4 inches outside, and $\frac{1}{2}$ inch thick, running into the two branches by fillets

and radii, as figured. The two branches are really one pipe, $2\frac{1}{2}$ inches inside, $3\frac{1}{2}$ inches outside, $\frac{1}{2}$ inch thick, and sweeping down into the square flanges by 4-inch radius.

This systematic method takes longer to explain than to actually execute, but it is typical of the train of thought which must be followed on all pieces, simple or complicated, in order to properly place dimensions.

In general, it may be stated that all parts of a piece must be referred either to each other, or to some common reference line, or to both. Each part so referred must then be figured as a piece by itself, and then its connections to the principal structure. Thus, figuring a machine detail involves three things:

- (1) Relative location of its parts.
- (2) Proportions of these parts.
- (3) Proportions of connecting members.

As in the original design of a piece so in the figuring of it, the draftsman must as far as possible put himself in the place of the workman, judging the methods and processes of construction and available tools. This will largely influence the arrangement of the dimensions. Of course it implies considerable experience in shop work, which some students do not possess. He can begin none too early, however, to learn to look at his work from the shop standpoint, and surely make it some better on that account.

Pieces must not only be systematically dimensioned, but regularly specified and called for by suitable titles.

A title should specify at least three things:

- (1) Name of piece.
- (2) Number wanted for one machine.
- (3) Material.

To these might be added a fourth; viz., pattern or piece number. The latter is not specified on the drawings under discussion, because systems of pattern and piece numbering are so varied that little would be gained by developing one for this special study.

These titles should always be put on in the same way, as the workmen become used to a certain system and are likely to misunderstand directions if a regular plan is not followed. A good way to arrange titles is suggested on the plates, although there are others which might be used.

Bolts are usually specified by diameter and length under the head, the length of thread being to some standard system in use by the shop, unless otherwise called for. Bolts are specified on the sheet containing the piece into which they are tapped. In the case of through bolts, tapped into neither piece, they are preferably called for in connection with the principal member.

Accuracy. Of course the dimensions on a drawing must be accurate. It is, however, a very easy matter to make errors. To insure accuracy a figure must *never* be put down carelessly, and a constant watch must be kept that scaled figures add up to over-all dimensions. It will not do to rely on scaling alone, as a very slight variation from exact scale may throw two dimensions out with each other. In spite of all the care that can be exercised errors will creep in, and a final thorough checking must be given a drawing before it is pronounced complete. A good rule to follow in checking up is to "assume everything wrong until it is proved to be right."

Clearness. As in the line drawing itself, there must be absolute clearness of instruction by the dimensions. Any doubt as to what a figure is, or what it means, rules out that figure as part of the drawing. If a piece is made wrong because doubt of this character is transmitted to the workman, the draftsman is always held responsible for the error.

Figures should, in all cases, be placed where they can be most clearly read. They should be bunched on a single view as far as possible, but not when greater clearness demands that another view be used. It hinders the reading of a drawing materially if the eye is forced to jump over large spaces of the sheet from view to view, to catch the several dimensions of a small detail. Usually it is easy to so group figures as to avoid this.

It is a good plan to keep dimensions off the body of the drawing, when it can be done so conveniently. It is not worth while, however, to go out of one's way to do this, as figures in the open spaces of a detail do not at all destroy its clearness.

Extended notes on a drawing to make it clear should not be required, but they should be used without hesitation if any doubt exists. An explicit note of instruction is the final resource for clearness when the art of drawing fails of its purpose, as it sometimes does.

Completeness. A detail is completely dimensioned when it shows *all* the figures necessary for the workman. Anything short of this is incompleteness. As modern shops hold the draftsman solely responsible for the design, the mechanic is not allowed to modify it by filling in any omitted dimensions. The only way to be sure that all the dimensions are on is to systematically go all round a piece inside and out, according to the method suggested under the paragraph on "System."

It is a good plan to always bear in mind that not only the machinist is to use the drawing, but also the pattern maker. For the benefit of the latter, special attention is desirable in figuring the cores. This saves him some addition and subtraction. In general, it has been found that less chance of error exists if mathematical work is not required of the shopman, all necessary data being furnished on the face of the drawing.

Character. By character in figures and letters is meant uniform style, height and slope, and a certain boldness peculiar to the work of the expert draftsman. The last is difficult for the novice to acquire. The student should not be discouraged because his efforts do not look like impressions from printers' type. Artistic excellence is the result of long experience, but is based on character. If the student can once get character into his work, the artistic feature will, with careful and constant practice, gradually develop. It is safe to say that there is no one element of a drawing which more positively stamps it as the work of an amateur than the character of the lettering, and every attention should be paid to getting out of the apprenticeship stage in this respect. Freehand lettering only is permitted in the drawings illustrated herewith. Ruled letters are seldom found on any working drawings, as the element of time involved is so great that few shops are willing to pay for it.

Uniform style requires that if capitals only are used in titles, they only must be used in notes and elsewhere on the drawing. If lower-case letters are used, they must be used in every part of the drawing. One style should not be mixed with another. The height of the letters should be limited by two horizontal lines, and though practice may render the upper line unnecessary, it takes but an instant to draw it, and uniform height is then assured. A good

height for titles of details such as are illustrated is $\frac{5}{8}$ inch. The height once chosen should be adhered to throughout the whole set. A medium, not a hard, grade of pencil (3H) will give the hand greater freedom. A great temptation exists to omit titles from the pencil drawing, simply inking them on the tracing. This is false economy of time, for in the end it will be found that enough time will be saved by the certainty with which the tracing can be made to more than pay for the labor on the pencil drawing. Again, it permits the tracing, in regular shop practice, to be made by cheaper labor than that which produced the pencil drawing.

Uniform slope is most easily acquired by the use of guide lines put in at frequent intervals. A small wooden triangle can be made, giving the required angle. The angle of the letters shown on the plates is 9 degrees, or about 1 inch slope in 6 inches. The question as to whether letters should incline backwards, forwards, or stand vertical, does not enter this discussion. Character is not affected by the slope. The student may choose whatever comes most natural to him, but having chosen, the character of his work will be spoiled if he varies it. The most difficult of the three is the vertical style; hence most draftsmen incline their letters. The backward slope is used on the plates of this shop drawing paper, thus giving the student opportunity to compare with plates in the earlier books, and follow his preference.

The effect of change of style, height and slope is shown in Figs. 2, 3 and 4, respectively. Attention is called to Fig. 5, which is a sample title, in which these points are corrected.

Principal Titles. The principal title of a drawing should contain at least seven items:

- (1) Name of principal details shown.
- (2) Name of machine.
- (3) Firm name and location.
- (4) Scale of drawing.
- (5) Date of completion.
- (6) Draftsman's signature.
- (7) Filing number.

To these are often added others, but for purposes of filing and reference the above at least *must* be put on. The filing number may or may not be put in the title frame, but it is really a part of it. It is often put in the margin below the title.

An arrangement of title should be established and then followed exactly, without variation either as to location on sheet or detail make-up. Abbreviated words are always permissible in titles, provided the meaning is clear. Special care must be taken in punctuation, however, as a title, whether abbreviated or not, has an unfinished appearance if the periods, commas and other necessary punctuation marks are not included.

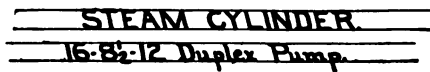


Fig. 2.



Fig. 3.

The sample title illustrated in Fig. 5 indicates the arrangement chosen for the drawings of



Fig. 4.

Part IV. Note that it is necessary in this special case to add an extra subject to the seven given above; viz., the residence of the student draftsman.

This style of title must be put with care on every drawing, even on the rough pencil layouts. In the latter case it may of course be left in pencil, as the rough layouts are not to be inked.

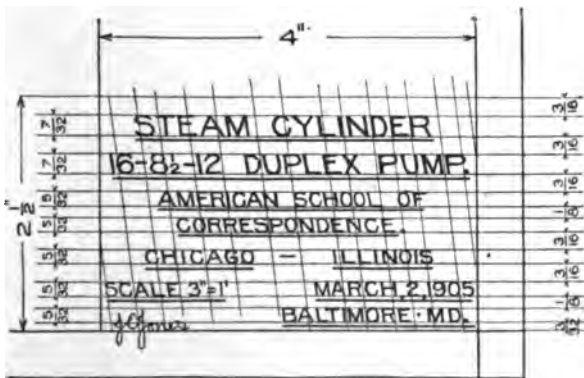


Fig. 5.

Inking and Tracing. Both bond paper and tracing cloth are used in business practice for finished drawings. It is desirable to

keep a stock of both in any drawing office, so that either may be used as occasion requires. Bond paper stretched on the board gives a beautiful surface to take the ink, and very handsome and effective detail or assembled drawings can thus be produced.

Changes are not quite as readily made on bond paper as on tracing cloth, and it takes a little longer to make the blue print. In other ways the bond paper is not quite as flexible to use as the tracing cloth. However, one must be guided entirely by shop conditions to settle the question of preference. As the tracing cloth is generally used, and suits the purpose of the student better, it will be required in this work.

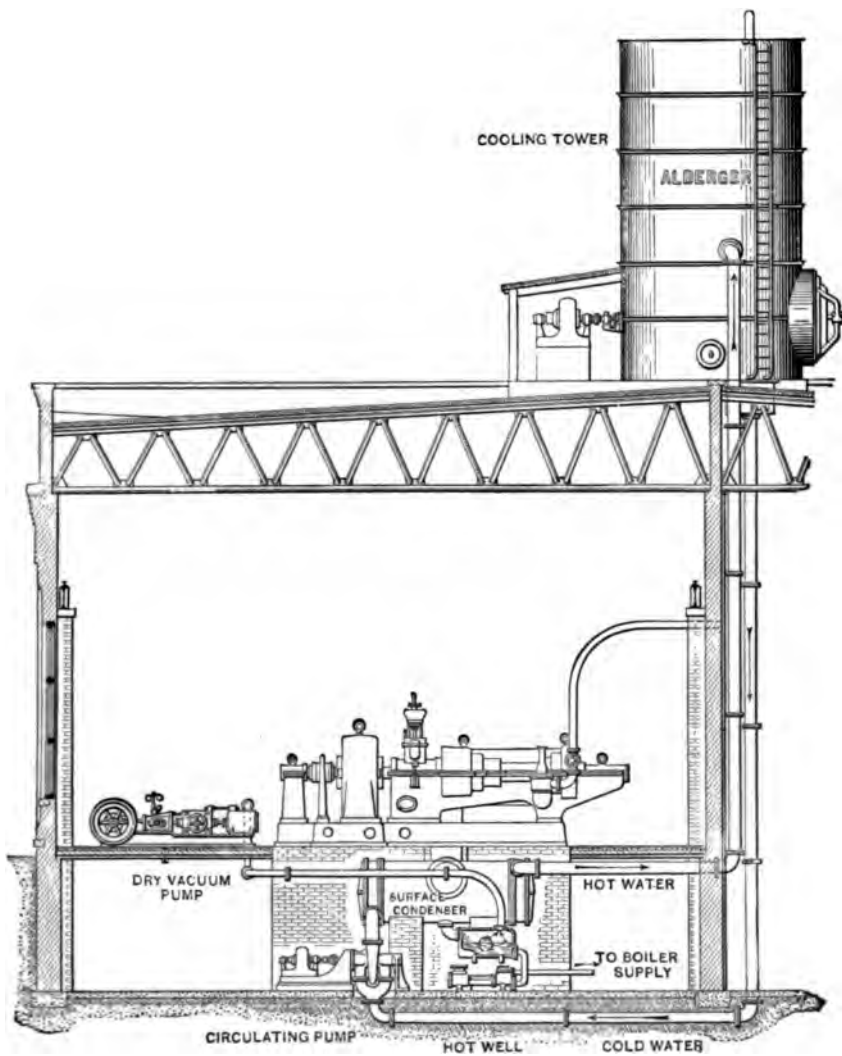
The inking should be done on the *rough* side of the cloth. One reason for choosing this side is that as the cloth tends to curl under toward the glazed side, the drawing as it lies right side up will tend to straighten itself. This seems to be a small point, but it is a very important advantage for filing and for the convenience of those who are to handle the drawings. Also the rough side takes colors and inks better than the glazed side. To trace on the glazed side is not wrong, for it is often done, but it possesses no advantages of its own, and has the disadvantage mentioned above.

Chalk dust scattered over the surface of the cloth after it is tacked down will remove the slightly greasy coating which prevents the ink from flowing well from the pen. This is always necessary if the glazed side be used, and usually for the rough side. The chalk must be carefully removed from the cloth before inking.

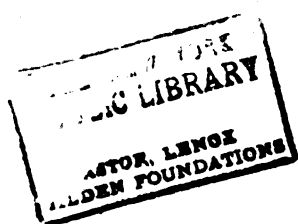
The first step in inking is to draw the center lines. Remember that *accurate intersections* are of the utmost importance. No circle is complete without two intersecting lines, preferably at 90 degrees, to determine its center, and these lines should be inked before the circle. When this is done a definite point exists for the needle point of the compasses. If the circle is drawn first the needle point may not be placed accurately at the center on the pencil drawing beneath, and the location be thrown out.

Likewise the principal center lines of pieces, the lines around which the pencil drawing was built up, should be at once put in.

The main body of the drawing, the full lines, should be taken next. In general, circles and arcs should be inked first, but there



COOLING TOWER AND SURFACE CONDENSER AS APPLIED TO STEAM TURBINE.
Alberger Condenser Company.



are cases where it is easier to run the arcs into the straight lines than to match the straight lines to the arcs. They are exceptions, however, and can be judged only as the case arises.

Straight lines, horizontal and vertical, should be inked with the T-square and triangle *in position*. It is a common practice to dispense with the use of the T-square entirely in inking in, using the triangle to match the lines to the arcs already drawn. A necessity for this implies very poor work on the arcs, for with any reasonable care true horizontal and vertical lines will match the arcs all right. With regard to time required, the accuracy with which the T-square may be brought up to a line, or the triangle set on the T-square, more than makes up for the time gained in even an approximate setting of the triangle without a guide. It is just as easy to cultivate the habit of holding the T-square and triangle with the left hand and the pen with the right, and draw an exact line, as to lapse into the other method, which is not workmanlike.

The lines of the body of the drawing depend for their width upon the size of the detail. For a large piece they may be $\frac{1}{32}$ inch wide, and the shade lines $\frac{3}{64}$ inch. For a small detail such widths would be too great. Remember that *contrast* is the principal aim, and to produce it is the only reason why we use different kinds of lines on a drawing. Hence the greatest care must be exercised to prevent body lines from becoming confused with center or dimension lines, and *vice versa*. Also thick lines are desirable for the production of a bold blue-print.

Shade lines are shown on Plates I, K and N only. They are put on according to principles already explained. They certainly improve the drawing from an artistic standpoint, and the student should know how to put them on when desired. Whether or not it is desirable to adopt them on all working drawings is not the purpose of this book to decide, or even discuss. Almost always drawings can be made perfectly clear without them, and are so made and satisfactorily used in probably the majority of shops. Some shops are willing to pay for the extra time necessary to put on shade lines; this, however, is purely their own investment.

Cross-section lines are usually drawn at an angle of 45 degrees with the horizontal, and on sections which are adjacent

to each other the slope should be in different directions. If three or more sections come together the width between section lines can be so changed as to indicate clearly the different parts. An example of this is shown in Fig. 6.

The spacing of section lines must not be too fine, rarely closer than $\frac{1}{16}$ inch, more often from $\frac{1}{8}$ to $\frac{1}{4}$ inch, else the labor involved is too great and uniformity practically impossible. It is a waste of time to rule in section lines on the pencil drawing; they may be sketched in freehand, as shown on the original layout of the steam cylinder. Even spacing concerns the tracing alone, and the student should train his eye to regularity as he traces. The thickness of section lines may be intermediate between that of center lines and body lines of the drawing.

Inking Dimensions and Letters. Extension lines may be dotted, as explained in Part III, or they may be fine, full lines, the latter method being illustrated in the series of pump plates in this paper. Dimension lines are also often made fine, full lines. If these lines are made full they should be made as firm as it is possible to draw them and still have them firm, clear lines. The same width should be used as for center lines.

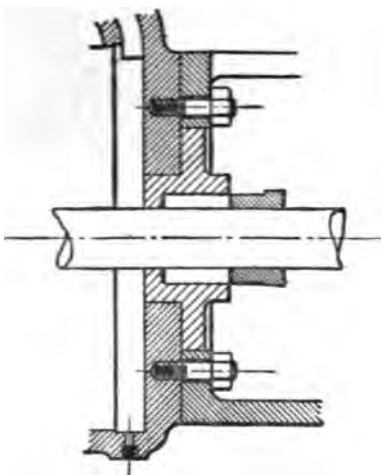


Fig. 6.

Character in inked figures and letters is more difficult to attain than in pencil work. In the first place a pen suitable to the style of drawing is necessary. A civil engineer's fine mapping pen, which gives character to his drawing, is not desirable in producing the bold character of a machine drawing. For the latter choose a rather stiff, blunt pen which is not "scratchy," but runs smoothly, making a line of uniform width. A pen with a round, or ball-shaped nib, recently put on the market, answers the purpose well for ordinary details. A bold, free stroke should be made with the idea of producing a smooth, even line, finished

at the first trial. The hesitating uncertainty of the beginner's hand produces a "shaky" letter, and going over a letter or figure twice or more to smooth it up usually makes it worse.

Figures and letters which are broad in proportion to height are easier to make, and have more character. It should never for a moment be forgotten that uniform *height* and *slope* carefully followed will develop character and quickly lead to artistic excellence.

Foot and inch marks are often put after figures according to the common usage. In cases where feet and inches are expressed, thus: 8' — 6", or 4' — 0", they are, of course, absolutely necessary, and the dash between the figures must be very positively indicated. In cases of inch dimensions alone the marks may be put on if desired, but where there can be no doubt that inches, and not feet, are meant, the inch marks are not necessary. This practice is followed on the plates of this paper.

Abbreviations. A list of the most common abbreviations in use on working drawings follows. This list has been adopted for the plates in Part IV:

F. A. O.	finished all over.
f.	finished surface.
R.	radius.
D.	diameter.
R. H.	right hand.
L. H.	left hand.
P. R.	piston rod.
P. TAP.	pipe tap.
CTRS.	centers.
C. I.	cast iron.
S. C.	steel casting.
Bz.	bronze.
C. R. S.	cold rolled steel.
T. S.	tool steel.
O. H. S.	open hearth steel.
W. I.	wrought iron.

Plate E. Piston Rod and Valve Stem. The piston is of the one-piece box type, with sprung-in rings. The width is reduced to $4\frac{7}{8}$ inches at the outside, so that if the piston strikes the cylinder heads it will not tend to spring and break off the narrow ridge of metal outside of the packing ring. The piston rod is fastened to the piston on a taper drawn in by a nut, and the

nut is checked by a $\frac{1}{4}$ -inch split pin. The packing rings are prevented from slipping round the piston by lugs fitting loosely in chipped recesses in the groove. These being at opposite sides for each groove, the leakage of steam through the split in the ring is minimized, for it must pass half way round the piston before it can pass through the split in the other ring. This is a simple, but fairly effective, device.

The packing rings are usually cast in the form of a cylinder of some length, turned to a diameter a little larger than the cylinder bore, cut off to the required width, and sufficient space cut out to permit being sprung in to the size of cylinder bore.

The location of the spool on the piston rod is not positively known, as the setting of the valve bracket may be slightly different from what the drawing calls for. Hence, instead of a dimension, the words "measure for" are put on, to indicate that the spool be located during the erection of the pump. The hexagonal flanges of the spool are convenient to hold the rod from turning while screwing on the piston and plunger nuts.

Molding and Machining. There are no special features connected with the molding and machining of parts on Plate E. The holes in the piston side walls are necessary to give supports for the core, the piston being cast on its side. These holes, after the core is cleaned out through them, are plugged as indicated.

Plate F. Steam Chest and Valve. The steam chest in this instance is located on the cylinder by fitting down over the ledge made by the valve seat. The side flanges also serve the purpose of guiding the valve. It will be noticed that the steam chest cover is $15\frac{1}{4}$ inches $\times$ $11\frac{1}{4}$ inches, while the steam chest is 15 inches $\times$ 11 inches. This allows a ledge of $\frac{1}{8}$ inch, all around which the cover overhangs the walls of the chest. The steam cylinder flange in order to correspond must likewise be $15\frac{1}{4}$ inches $\times$ $11\frac{1}{4}$ inches. The reason this is done is because of the difficulty of making good matched joints between the cylinder flange, chest and cover. The practice of thus leaving a little ledge all round is by no means universal, and often the irregularity in the joints is smoothed off by chipping. This is the case with the other flanges on this pump. The steam chest, however, was thought less likely to match properly, and the slight overhang gives the finished appearance of a sort of beaded edge.

The valve is what is known as a "square" slide valve. This means that when the valve is placed central on the ports its working edges are "square" with the ports ; that is, in exact line with them. If the valve be moved either way from this position, the slightest travel will admit steam to one end of the cylinder and exhaust it from the other. (See Plate A.) Another way of stating this is to say that a "square" slide valve is a slide valve without "lap."

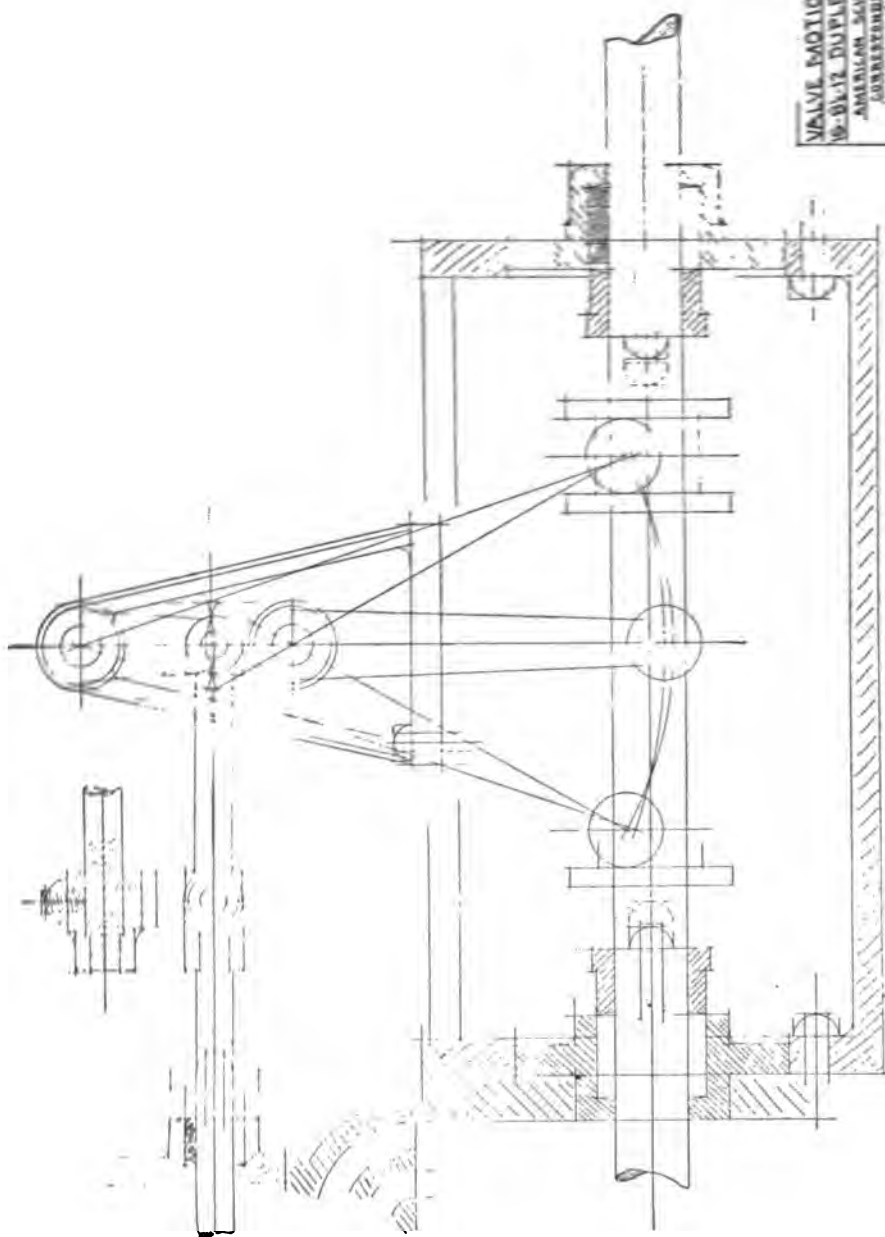
The valve is driven from the valve stem by the striking of the nuts against the lug on its top. Since the valve is already guided on its edges by the steam-chest flange, the valve stem, to avoid springing, must be perfectly free in the slot cast for it, as is shown by the $\frac{5}{8}$ -inch radius of the bottom, the stem being 1 inch in diameter.

The steam-pipe flange is made square to keep the height of the chest as low as possible. The radius of the bend should be ample ; in this case 4 inches is considered sufficient.

The exhaust tee must have its upper flange high enough so that the chest cover can be lifted and slipped off the studs without interfering with it. The lower flanges should be made wide enough to permit the tap bolts to be put in without striking the 4-inch vertical pipe, 5-inch centers being necessary. The $\frac{1}{4}$ -inch drip-cock, as located, readily drains the steam chest and exhaust passage of both cylinders, as well as the exhaust tee.

Molding. It is evident that the steam chest will be molded in the position shown on the drawing. The parting line of the mold will be through the centers of the steam-pipe opening and the stuffing-box. These holes must be cored out. The main body of the chest could be made to leave its own core, but it may not be made in this way. It may be cheaper to fashion the pattern solid, and make one large core-box for the inside. In this way the pattern will probably hold its shape better and require less repairs, than if it were made in green sand. The core-box will be an extra piece to make, but it probably will cost no more than to carve out the inside of the pattern, and is a rather more substantial job when done. The molding can be satisfactorily done by either method, shop conditions being the controlling element. As far as the labor of molding alone is concerned, the first method is probably easier, as it saves handling large cores.

VALVE MOTION LINKAGE
V-8-12 DUPLEX PUMP
AMERICAN SCHOOL OF
ENGINEERING
CHICAGO - ILLINOIS
RECAR. 8-11



The other parts in Plate F are very simple in their molding, and require no special attention.

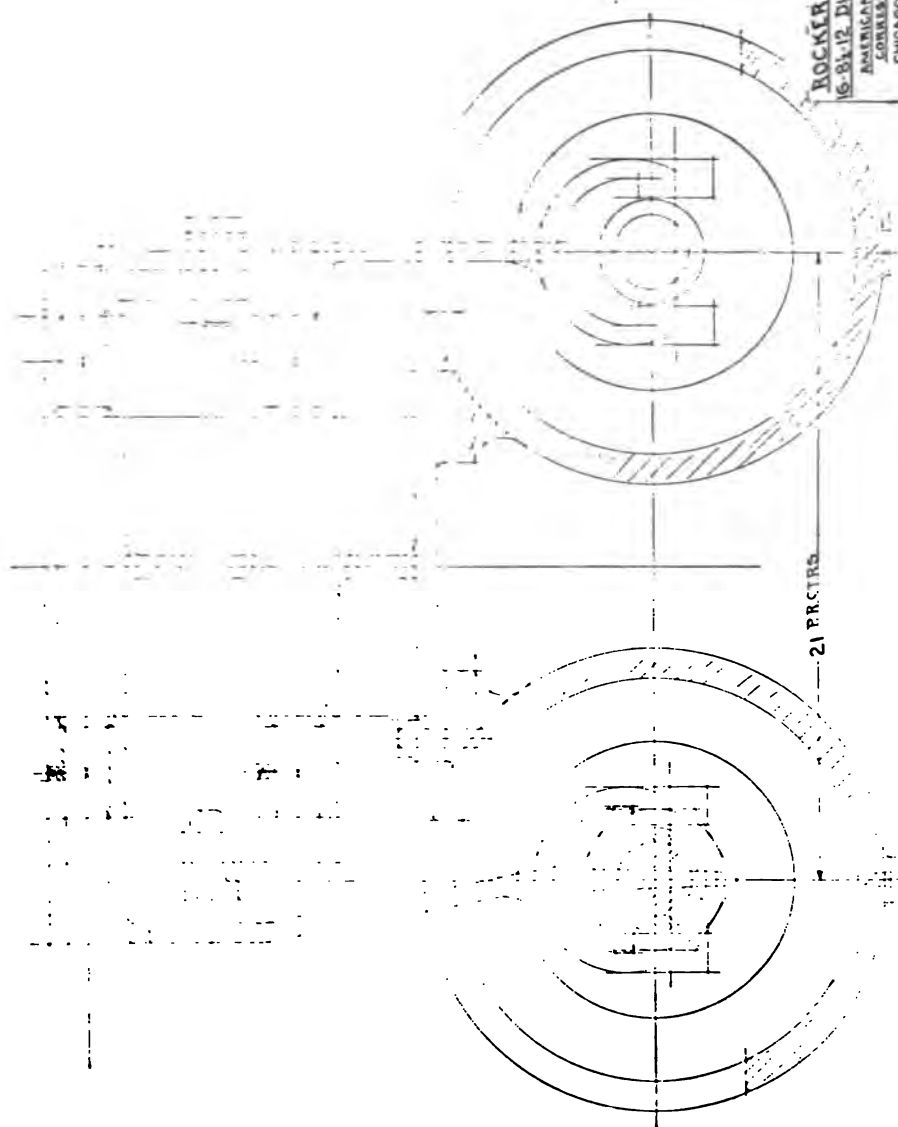
Machining. Most of the surface work on this plate is adapted to the planer. The slide valve may, perhaps, if finished in lots of considerable number, be more satisfactorily handled on the milling machine. The final finish of the face of the valve must be a scraped fit to its seat.

The drilling of the cover and pipe flanges is to actual layout on the casting, or preferably, through jig plates. A templet for laying out is at least desirable, even though the expense of a jig plate be not deemed necessary.

Plates C and D. Valve Motion Layout. These plates represent the layout of the valve motion, and are necessary in order to find the length of the levers and rocker arms. It will be noticed in Plate D that the valve stem of one side of the pump is controlled by the movement of the piston-rod of the other side, the proper direction of motion being given to the valve by placing the rocker shaft above or below the valve stem as required. By reference to Plate A it will be further noticed that the nuts on the valve stem inside the chest, which abut against the faces of the lug on the valve, do not rest against the faces of the lug in the position shown, but have considerable lost motion. This lost motion is one of the essential features of the valve motion of a duplex pump, and permits the valve to remain at rest for a short period at the end of the stroke, though the valve stem may have reversed its motion and begun its return stroke. When this lost motion is taken up by the movement of the stem and the nuts abut against the lug on the valve, the valve will move, and from this point to the end of the stroke be positively controlled by the motion of the stem. At the end of the stroke the stem will reverse, when the lost motion will again permit the valve to rest for the same period as at the other end, and then move on as before. The time of rest of the valve, and consequently the pistons and plungers, is approximately one-third the period of the stroke. This means that the piston on one side travels one-third of its stroke before it picks up, through the valve levers, the valve on the other side. During the second third of its travel it is bringing the

ROCKER ARM LAYOUT
16-8 1/2" DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE,
CHICAGO - ILLINOIS
SCALE - 8" = 1'

21 P.C.T.R.S.



valve to the point of opening. During the last third of its travel it is opening the port, wider and wider, to steam. Thus the opposite piston will start when the first piston has covered two-thirds of its stroke, and there will be only one-third of the stroke when both pistons are moving at the same time.

This relative period of rest to motion is not always made in this exact ratio, but is at least approximate to it. The period of rest at the end of the stroke is to allow the water end to adjust itself quietly to the reversal of motion about to take place at the end of the stroke. When the plunger stops, the water valves must be given time to seat themselves, and the flow of water through the passages checked. It is much easier to start the flow in the opposite direction if the reversal of plunger motion is not instantaneous. Hence for handling long columns of water, which, once in motion, tend by considerable energy to remain in motion, the duplex pump by this peculiar delayed action has been found to be well suited.

It will be found that for complete uncovering of port, and motion divisible into thirds as described, the travel of the valve stem should be three times the width of port, or $3 \times \frac{7}{8}$ inch = $2\frac{5}{8}$ inches. A little more than this is allowed, and the travel made $2\frac{7}{8}$ inches in this case. Referring to Plate C, this distance is laid off as shown by the two limiting vertical lines across the line of the valve stem, the central vertical line of mid-position being drawn. The problem then is to find such centers for the rocker arms that the travel of the piston-rod spool will, through proper leverage, produce travel of the valve stem between these two vertical lines. This can readily be done by a few trials, the only requirement for this case being that the extremes of the arc of swing of both piston-rod lever and rocker arm shall be equally above and below the center of piston rod and valve stem respectively. The greatest possible travel of the piston-rod spool, $12\frac{1}{2}$ inches, is usually laid out in this case, not the nominal 12 inches.

From this layout the lengths of the levers and arms may be scaled off for the detail drawing, also the location of the rocker-arm centers. The student has the former given him on Plate K, but the latter, which is necessary for the development of Plate L, must be determined by his own layout. Plate D must also be



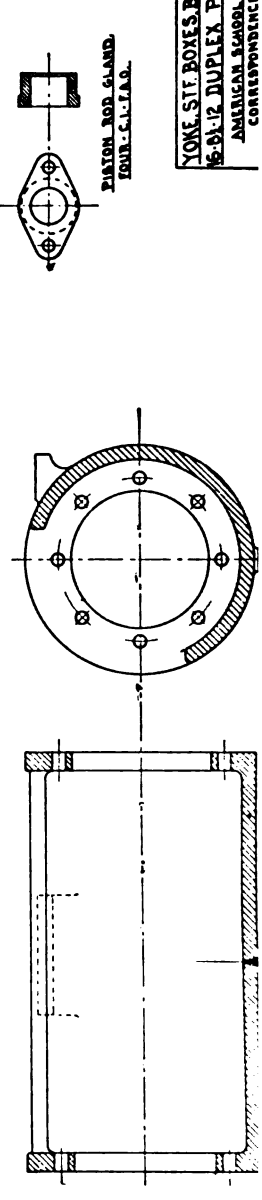
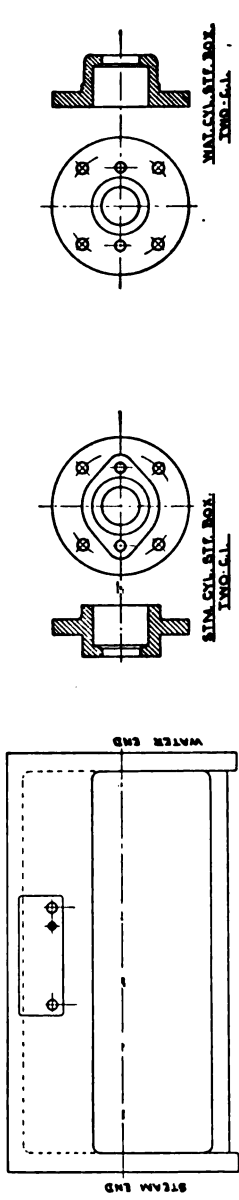
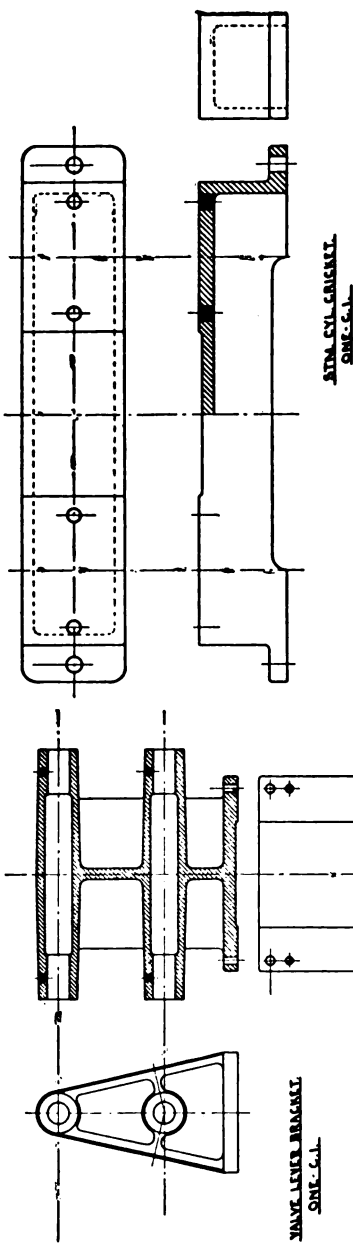
laid out before developing the cross-section of the valve bracket.

The design of stuffing boxes for both steam and water ends, and the length of the yoke, should be determined next. A safe method of assuming clearance between the spool and the gland studs at the end of the stroke, is to imagine that the gland stud nuts have accidentally worked off the studs, so that they are about to drop. They are thus shown by dotted lines on Plate C. A good clearance, say $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, is then allowed, and the gland drawn in. The length of the gland is determined by the number of rings of packing necessary in the stuffing box; it is usually provided that the gland may compress the packing to about one-half its original depth before bringing up against the face of the box. Packing $\frac{5}{8}$ inch square will do for this size of piston rod, hence the faces of the yoke are easily determined, and its detail, with the stuffing boxes, proceeded with as on Plate L. The length of yoke may be brought to an even figure; and proceeding on the above plan the length can be conveniently made in even inches without any fractions; viz., 28 inches.

It will be noticed that the stuffing-box flanges serve to center the yoke in line with the steam and water cylinders. This is a desirable feature of construction, and forms a simple and easy method for lining up the steam and water ends.

Plate K. Valve Motion Details. The piston-rod levers on this plate are specified to be steel forgings. Forgings of this kind are expensive, but are light, neat and reliable for the important service which they have to perform. Castings, whether steel or iron, are much cheaper, and perhaps more commonly used for this detail. When sound they are equally serviceable, though of more clumsy proportions; but the danger in castings of this form is the existence of hidden flaws or pockets, which frequently occur at the points where the hub or the fork joins the arm. These flaws cannot be readily detected from the outside, and breakage may occur at some critical time, when the disability of the pump may be a serious matter.

The use of shade lines is illustrated on this plate. The increased artistic effect is noticeable, but it would seem that absolute clearness would still exist, even if shade lines were not used.



It will be noticed that on the detail of the "link pin" two of the dimensions have a short "wavy" line beneath the figures. This is one of the several ways of indicating that the dimension is "out of scale." Some draftsmen use a straight dash beneath the figure; some draw a circle about it; some print after the figure, "out of scale." Although workmen are not allowed to scale drawings, but are required to "work to figures only," yet for general safety's sake, and for the sake of the draftsmen who consult the drawings frequently, attention must be called to any variation of the figure from the measured distance on the drawing. Nothing makes a workman, or any one else who reads a shop drawing, lose confidence in it more quickly than to discover that it does not "scale"; but when no indication exists that the draftsman himself is aware of it, then every dimension is viewed with doubt and hesitation, and the drawing becomes practically worthless.

Dimensions seldom should be out of scale; but if they are, through error or necessary change, a carefully worded note should be added.

Molding and Machining. No special features of molding or machining are noteworthy on Plate K.

Plate L. Yoke, Stuffing-boxes, Bracket, etc. Having worked up the layouts of Plates C and D, the student has enough information to proceed with Plate L. This, like Plate G, is without dimensions, the student's work being to make the drawing and fill in the necessary shop data.

The valve-lever bracket is bolted down to its lug on the yoke through holes larger than the bolt, thus permitting slight adjustment. When the proper location is determined, the bracket is positively fixed in position by two dowels, $\frac{1}{2}$ inch in diameter. The holes in both bracket and yoke are drilled through both pieces at the same operation. This very common method of fixing bolted parts of machinery in absolute position not only assures firmness, but also in case of removal, permits the part to be readily and positively replaced in its exact original position.

If possible, the steam cylinder cricket should be of such height that the stone or brick work upon which it rests shall be at the same level as that beneath the water cylinder. The tapped

holes in the top surface receive bolts from the cylinder foot. These bolts are often used only for shipping purposes, the cylinder foot when the pump is set up being allowed to slide freely on the cricket, thus permitting free expansion and contraction. In such cases the water end is rigidly fastened to the foundation by holding down bolts.

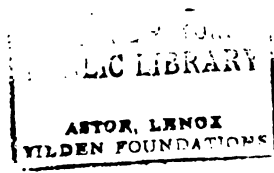
Molding and Machining. The valve lever-bracket would most naturally be molded with the axes of the shafts vertical, the parting line of the mold being the center line of the middle web. This makes quite a long "draw" for the shaft bosses, but the ample taper on the outside overcomes this difficulty. The space between the side webs leaves its own core. The shaft cores stand on end in the mold, which is the best position for strength and stability.

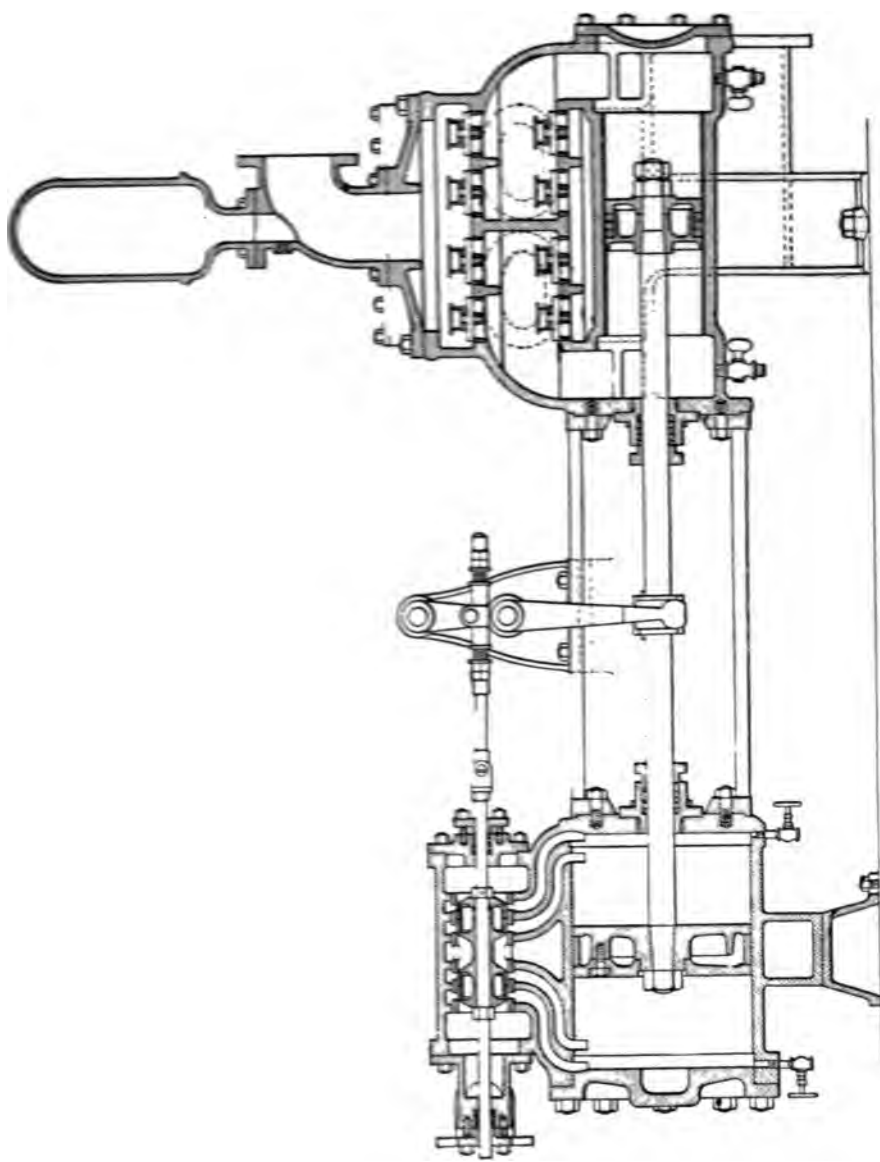
Another method is to have the parting line of the mold on the vertical center line of the bracket, as shown in the end view. In this case the bracket would be cast on its side, and cores must be set for each side of the middle web. The shaft cores are set as easily as before, but in this case lie flat. As with the steam chest, each method has its advantages, which depend largely upon existing conditions. As cored work is generally avoided whenever possible, the first method would probably be chosen.

The shaft bosses are "chamber-cored," to save labor in boring, the bearing surface for the shaft being only a short distance at the ends. The chamber-core diameter should be enough larger than the shaft so that by no possibility can the cutter run into the rough scale, even if the hole be bored slightly out of line. If it should do this, the labor of caring for the cutters more than offsets the attempted saving of labor.

The yoke is simply a barrel open at each end, and with a piece cut out of its side. The inside evidently must be cored out, and the core is satisfactorily supported at the ends on its horizontal axis. The parting line of the mold may be either the vertical or horizontal axis of the end view, the only difference being that in one case the ledge for the valve bracket will "draw," and in the other case it must be loose on the pattern and "pulled in" after the main pattern is drawn.

The cricket and stuffing boxes present no difficulties. The





CROSS SECTION OF DOUBLE ACTING STEAM PUMP.

bore of the stuffing boxes and glands should be from $\frac{1}{32}$ inch to $\frac{1}{16}$ inch larger than the rod, to allow the fit to be entirely between the rod and the packing.

The horizontal boring machine with a double facing head is adapted to boring and facing the yoke flanges. The drilling is accomplished as before by templet or jig.

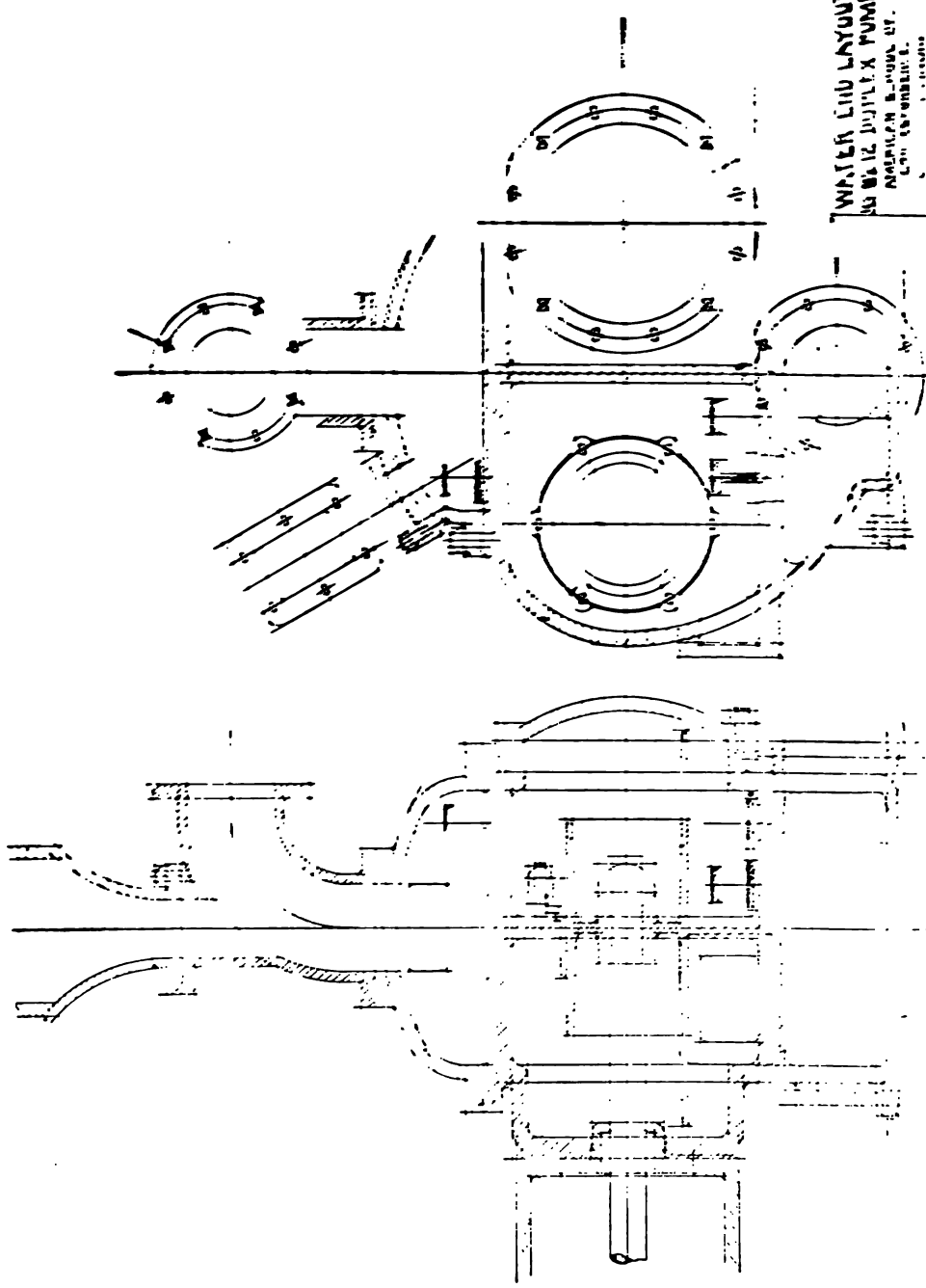
Attention is called to the tapped holes for oil or grease cups on the valve-lever bracket. The holes on the lower boss cannot be drilled strictly as shown, because the drill shank will not clear the upper boss. They should be swung around the boss at such an angle as will allow the drill to clear. This is a good instance of the common error of drawing details which cannot be made, and constant watch must be kept to avoid such mistakes.

Plate B. Water End Layout. As in the preceding work, Plates H and I being given in full detail offer a good start for the development of the water cylinder, which is the purpose of Plate B. As before, work should begin at the inside and progress outwards. Thus the piston rod with its nut should be drawn first, the hub of the plunger built around it, then the plunger barrel, the bushing, and ring to clamp the bushing. The limits of the plunger travel should be sketched in, and the valve outline shown in order to determine clearances. The progress of Plate B is on exactly the same basis as that stated in detail for the steam cylinder layout; hence it need not be repeated.

The points controlling the design of the water end must, however, be studied to enable the student to work intelligently. The fit of the rod into the plunger hub is loose, $\frac{1}{16}$ -inch play being allowed, in order to permit the plunger to be guided solely by its bushing, and thus be independent of any change of alignment of the piston rod.

The relative length of plunger and bushing should allow the end of the plunger to overrun the edge of the bushing at the termination of the stroke, to prevent the formation of a shoulder. The bushing is made of brass because of the better bearing of the two dissimilar metals, brass and iron. Of course there is no lubrication except the water, and the dissimilar metals tend to "cut" less than if both were alike. The brass bushing also prevents the plunger from "rusting in" in case of long periods of

WATER LIND LAYOUT
NO. 12 DUPLEX PUMP
NORTHMAN & SONS, LTD.
LONDON, ENGLAND



disuse. The bushing being of expensive material is made as light as possible, hence it has no stiffness of its own. Therefore it is reinforced by a deep cast-iron ring, which also takes the bolts and clamps the bushing tightly to its ground seat. These stud bolts are usually made of "tobin bronze," a rust-proof material, possessing strength almost as great as that of steel. This arrangement permits ready removal of the bushing when necessary.

As the parts of the common pump valve illustrated in detail on Plate H must be often replaced during service of the pump, provision must be made for unscrewing the stem and substituting a new one. This must be done through the hand holes provided on the cylinder. The lower valve deck must be located so that the inner valves when unscrewed will not strike the clamp ring. As shown in Plate B the clearance is pretty small, almost too small, but as it affects only two valves, it will probably cause no inconvenience. No hand holes are necessary for the end chambers, as access to the valves is had by removing the outer heads. The upper deck may be placed at a height giving sufficient clearance to allow the upper nuts of the clamp ring to be unscrewed with a socket wrench from the end of the pump. These decks are subjected to a severe pounding from the pulsations of the pump, and should be amply strong; $1\frac{3}{4}$ inches is deemed thick enough for this case.

The middle transverse wall may be $1\frac{1}{2}$ inches thick and the middle longitudinal wall a little thinner, about $1\frac{1}{4}$ inches. With high pressures these walls, being flat surfaces and the valve decks likewise, are likely to fracture under the heavy pounding. To avoid making them excessively heavy they are often strongly ribbed, either on the inside or outside, usually the former.

The curving side walls are of better form to withstand pressure, and need not be as thick, 1 inch being sufficient. This can be decreased to $\frac{3}{4}$ inch in the suction passage below the deck, where little pressure exists.

The outer head is also considered strong enough at 1 inch thickness, on account of its curved shape. It requires $\frac{7}{8}$ -inch studs. Studs are preferred to tap bolts in this case, as in all other similar cases, on account of the frequent unscrewing of the nuts for purpose of removal. One or two unscrewings of a tap bolt in cast

iron will destroy the tightness of the thread, while the stud, being steel, stands the wear better.

The valve seats are taper screwed into the deck; they are sometimes forced in on a plain taper fit. They are located as closely as strength of the deck between the holes will permit. It is not well to place the edge of the valve closer than $\frac{1}{2}$ inch from the cylinder walls. The valve holes in the lower deck should be in line, or nearly so, with the holes in the upper deck, in order to allow the shank of the mill to pass through when milling the lower holes.

The suction opening is 7 inches in diameter, 12 $\frac{1}{2}$ -inch flange, 10 $\frac{1}{2}$ -inch bolt circle, $\frac{3}{4}$ -inch tapped holes.

By means of the hand hole at the end of the suction passage, any dirt which may have been brought in through the suction pipe may be removed.

The water cylinder cap, discharge ell and air chamber may be laid out from the detail Plate I, and the student must do this to see that the parts actually go together properly.

With the foregoing discussion the student should be able to produce Plate B, which is the preliminary step to the detail drawing of the water cylinder as shown on Plate J.

Plate J. Water Cylinder. The water cylinder is, perhaps, the most complicated detail that the student will meet in this set of plates. Fundamentally, it is simply a box with curved sides, divided by the several walls into five compartments, each of which communicates with the outside by a round nozzle or flange. If this basic idea be kept constantly in mind, the student will have no trouble in building up the detailed design.

This fundamental conception of a complicated piece is a very important idea, and should be developed carefully by the student. It is one of the great secrets of good design, both from an artistic and a commercial standpoint. We often see a machine which seems to begin anywhere and end nowhere; it appears to be a miscellaneous collection of bosses, lugs, ribs and flanges. There is no general prevailing shape to the structure, no harmony of the lines. This is because the designer, if he may be so called, did not have the fundamental notion of shape, to which all minor details should have been subordinated. He simply grouped

parts together, without considering the fundamental structure.

In this water cylinder the box is the basic part of the structure, and its lines must be first developed; they should be designed to convey a smooth, regular and consistent surface to the eye. Then the nozzles and flanges may be added as subordinate parts; they will merely interrupt, but not destroy, the prevailing outline of the box. The dotted lines in the cross-section views of Plate J show the general shape behind and beneath the nozzles.

The hand holes are the same as on Plate I, and the detail of the cover should specify the number required for both places.

Provision for draining the four chambers of the water cylinder is made by the $\frac{3}{8}$ -inch pipe tap holes at the lower deck, and the cap, likewise, by the single hole at the upper deck. Drip cocks are screwed into these holes.

The holding-down bolts should not be less than 1 inch diameter; $1\frac{1}{4}$ inch would perhaps be better; and the holes in the foot should be drilled at least $\frac{1}{8}$ inch large.

Dimensions. It will be noticed that this plate has dimension lines, but no figures. This is because the cylinder is rather difficult to figure, and it is desired to guide the student in arrangement of the figures without lessening the benefit of his study of them. Special attention should be paid to this feature of the plate. Notice that although space for dimensions is restricted, a clear opening is always found for the figures; and when one view seems to offer no space for a figure, another view gives the desired opportunity.

No finish marks or titles are shown on this plate, these being left entirely to the student for insertion.

Molding. The centers of the curves for the sides being on the main horizontal axis of the nozzles, the cylinder, if molded to be cast vertically as shown, will draw readily both ways from this line. The exceptions to this easy draw are the foot, suction nozzle and flange, and hand-hole boss. On account of the inside of the cylinder being cored, these pieces if made loose on the pattern have ample space to be "pulled in" after the main pattern is withdrawn.

The suction passage below the deck communicates with the main core through the valve holes, hence it may be supported

from the main core. This involves some difficulty, however. If a three-part flask be used, and another parting established at the center of the suction flange, in addition to the previous one, the problem becomes much simplified.

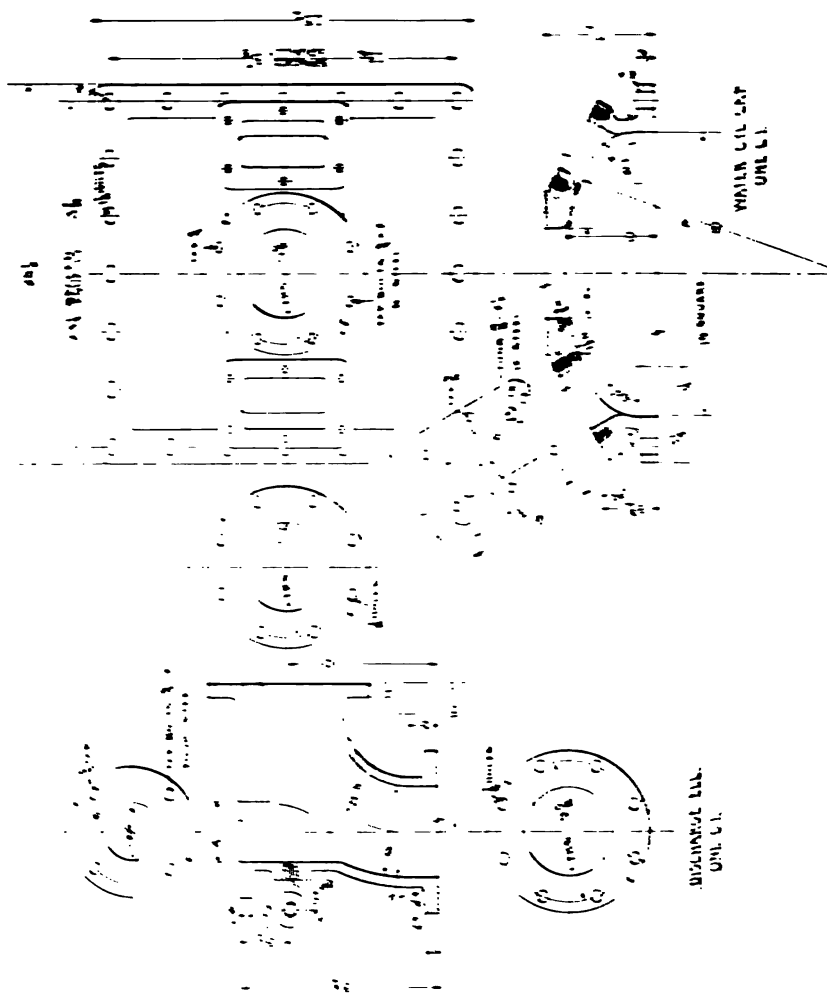
It is desirable to make the four chambers of the cylinder alike in general proportions. It is then possible to make a single core-box, and by the use of loose pieces change the length of the nozzle cores and transpose from right to left, thus saving labor on the pattern. This, however, multiplies the loose pieces on the pattern. The many pieces are likely to become lost and make frequent repair necessary. Hence it is not always wise to use a single core box too much, and good judgment is required to fix the limit.

Machining. Special double horizontal boring machines are now in common use for such cases as this water cylinder. The centers are made adjustable, so that within limits any distance between piston-rod centers can be met. The advantages of double boring are, of course, most obvious for a considerable number of duplicate cylinders.

It will be noticed that the face of the suction flange is carried out flush with the cylinder head face. This affords opportunity for finishing all the end surfaces at a single setting of the tool, whether the work be done on the rotary or reciprocating planer. This same point might have been observed on the small hand-hole boss at the other end of the cylinder, but the advantage gained did not seem to warrant extending the "reach" through the hand hole.

Plate I. Water Cylinder, Cap and Air Chamber. For a water cylinder cap of this size, the most difficult problem is to find room for the hand-hole bosses. A hand hole 4 inches $\times$ 6 inches is about as small as can be used, and this calls for a flange at least 7 inches $\times$ 9 inches. These are the proportions shown on the plate, and since the boss overhangs the bolts in the main-cap flange, it must be cut away underneath to clear the nuts. If three stud bolts are used on each side, this overhang also requires that the nut be "fed on"; that is, screwed on little by little as the end of the stud protrudes above the flange when the cap is being lowered into place. This is an awkward process, but is sometimes necessary.

WATER CAP & AIR CHAMBER
 16 DL 12 DUPLEX PUMP
 AMERICAN SCHOOL OF
 CORRESPONDENCE
 CHICAGO, ILL. U.S.A.



The discharge ell should have an easy bend; usually the radius is somewhat more than the outside diameter of the pipe, in this case 50 per cent greater. It is customary on this piece to provide an opening for the attachment of a relief valve as shown, $1\frac{1}{4}$ -inch pipe tap. This valve can be set to open at a desired pressure, so that the water end may be relieved in case of accidental excessive pressure.

The air chamber provides an air cushion for the water to make the delivery more constant, and take the shock which would otherwise come with hammer-like force and full intensity upon the cylinder. Being placed at the highest point of the water end, air will naturally tend to collect in the air chamber and keep it charged. In some cases, however, a special charging device is necessary.

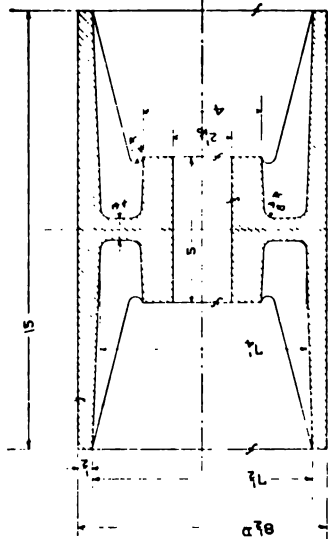
Molding and Machining. The hand holes being at an angle will not "draw." Hence cores must be set for these openings at least, and it may be desirable to core out the whole inside of the cap for the sake of keeping the pattern in good shape by making it solid. Otherwise it is easy to let it leave its own core.

The overhang of the hand-hole bosses requires loose pieces for the overhanging part. They are "pulled" in after the pattern is drawn.

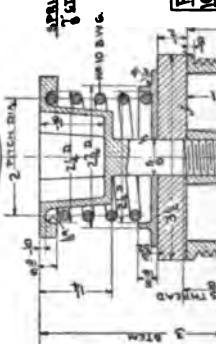
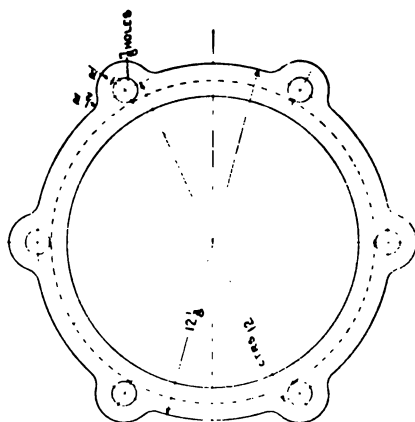
The molding and machining which are further required on details of Plate I are simple, and require no special discussion.

Plate H. Plunger and Valve Details. This plate is noticeable for illustrating a method of drawing details not used elsewhere in this set of plates. On the other plates each piece is separately detailed. On Plate H the details of the valve, cover, seat, stem and spring are shown assembled, and dimensioned without separation. This is an allowable method when clearness is not sacrificed, but it is usually found desirable only with simple construction. It concentrates parts on the drawing, and probably saves some time, besides showing the workman just how the parts go together. The only test which the student need to apply in this, as in any method of detailing, is the test for absolute clearness.

It is believed in the case of the valve as shown that the details are completely illustrated without sacrificing clearness. Special care in putting in dimensions is of necessity required.



PLUNGER.
TM9.C1



COVER.
22. NAME.

SPRING-WIND YOUR FUL-CONS.
7' LTR. 10 LTR. OF CAR. WHEN OPEN
32- BRASS WIRE.

PLUNGER & VALVE DET.
16-81-12 DUPLEX PUMP

The valve stem can be unscrewed either with a socket wrench on the inside or an ordinary fork wrench on the outside.

The seat, after being screwed to position in the deck, is often faced off, to true up any distortion caused by screwing in.

The valve itself, of rubber, can be bought of any desired grade of hardness. The specification for any given set of valves depend upon the quality of the water, the pressure and the general service of the pump.

Molding and Machining. By reason of the simple nature of the parts on this plate, the molding and machining is left entirely to the original consideration of the student.

Plate M. Foundation. Pumps are often set directly upon a foundation of brick, but it makes a better job to bed stones, with surfaces dressed plane and true, into the main foundation, and rest the pump feet upon these stones. The simplest form of holding down bolts are shown on Plate M, a plain hook at the lower end, pulling up against a flat cast-iron plate, to distribute the pressure into the brickwork. These plates are of course bedded, and the bolts set as the foundation is built up. As the subsequent courses are laid some little space is left around the bolts, which may be afterwards filled with cement, thus making the bolts rigid with the foundation.

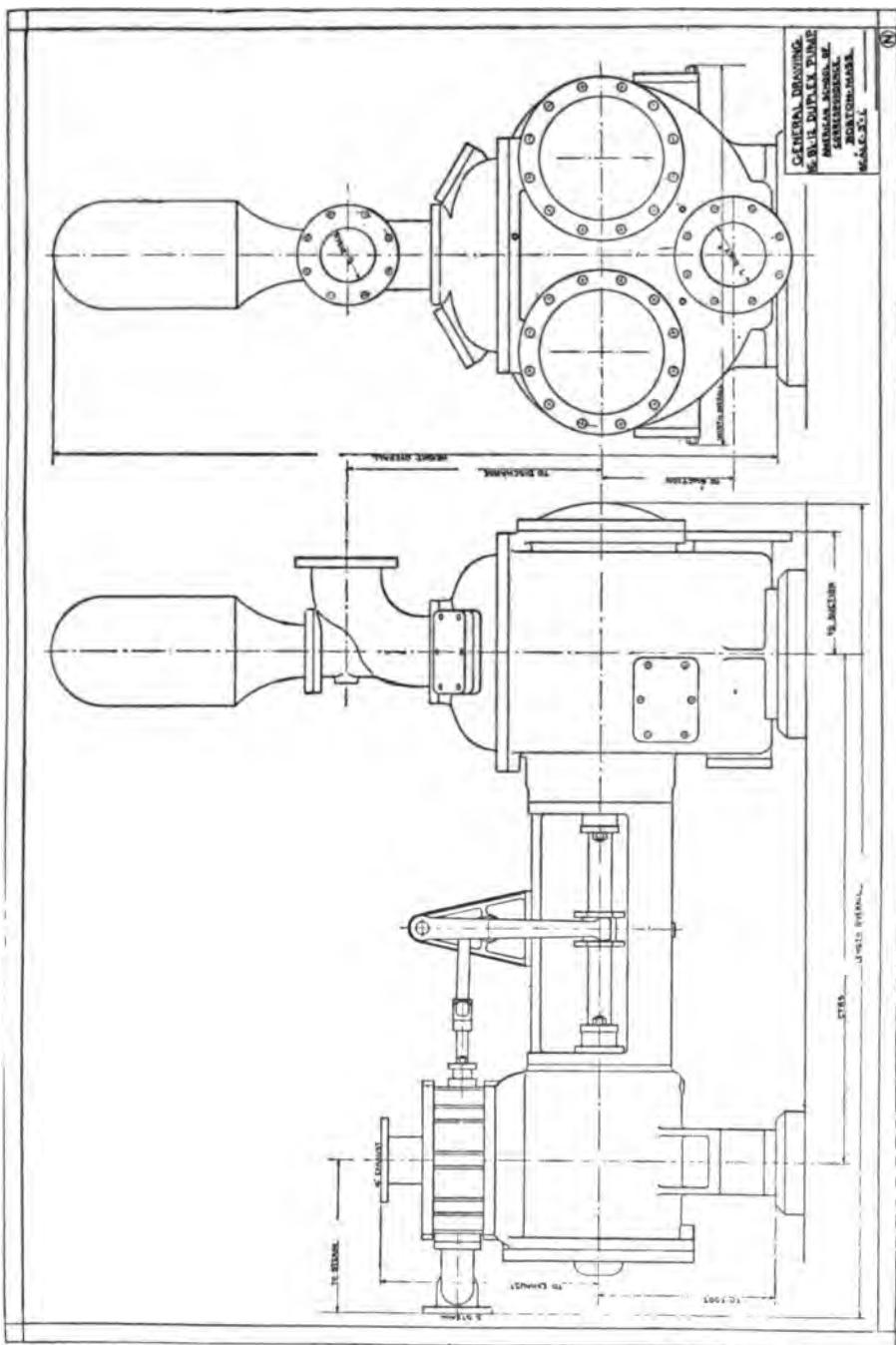
The water end of the foundation has no batter, because the suction pipe often drops vertically down from the end of the pump, and clearance is therefore necessary.

The floor line is placed 4 inches above the brickwork, to allow for the usual 1-inch top floor and 2-inch plank beneath, and still have a space left for shims to level the floor.

Plate N. General Drawing. This is an example of a plain, everyday shop drawing, to show the relation of parts and the extreme space occupied by the pump. A great deal of time can be needlessly wasted in producing a drawing of this character, by trying to make too faithful a picture. For example: If all the bolt heads were put in, it is safe to say that several hours' extra time would be required for this one item alone. But the drawing would be no better for shop use. Hence all bolt heads and nuts have been left out, except when necessary to show clearance.

Shade lines have been put on for no special reason except

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that if they are desirable on any drawing they are especially desirable on a general drawing, where one part overlaps another, as they make it easier to pick out and separate one surface from another. Some lines are shaded in this drawing which are not strictly sharp edges. It is held, however, that the rounding of a corner ought not to destroy its character as an edge casting a shadow, and such lines are treated accordingly.

An assembled or general drawing of this character should be laid out strictly from the dimensions shown by the details. It thus serves a valuable purpose in checking up figures, and showing whether or not the parts will go together. The method or character of the work in no respect differs from that suggested for the detail drawings.

If a scale of 3 inches = 1 foot be used, the size of sheet must be 24 inches $\times$ 36 inches. The student, however, will perhaps find it easier to use a scale of $1\frac{1}{2}$ inches = 1 foot, in which case the ordinary size, 18 inches $\times$ 24 inches, will suffice. For such a small scale it will be found undesirable to attempt to put in any very small fillets and corners, although those that can be readily handled by the ordinary bow pen ought not to be omitted. As a matter of fact, the expert draftsman either leaves the corners sharp, as suggested, or puts in the smallest curves freehand.

Order Sheets. Any set of drawings is incomplete unless in connection with it a statement is made in tabular form of the complete make-up of the machine. An infinite variety of ways exists for making the specifications. Sometimes the tabulated data are placed on the general drawing. Most often, however, printed blanks are provided, usually of bond paper, arranged with special reference to the individual shop system and methods of handling work; these blanks are filled in by the draftsman, indexed and filed as a part of the set of drawings. They can be blue printed for use in the shops the same as a drawing. From these sheets stock is ordered, checked off, and watched in its process of manufacture.

Order sheets are indispensable in any well-ordered shop. Hence they are illustrated on pages 59, 60, 61 and 62 as the final step in the set of pump drawings. They are made as simple as possible, and are not intended to fit any special shop system. As

previously stated, the exact form and method of classification can be determined only when the shop conditions are known.

The student, having carefully followed through the preceding pages, must not think that he is master of pump construction, for even the type illustrated has been but touched upon. The object of the detailed discussion is to get the student in close touch with the spirit of construction, to make his drawings real serious work. It is hoped that the student will work just as though a machine were to be built from his drawings, and built to sell at a profit. Only in this way can advanced work in mechanical drawing be of benefit to him, for after becoming expert in the use of the instruments, no other advance is possible except advance in *thought*.

MECHANICAL DRAWING.

59

DATE. MAY 20, 1902.		AMERICAN SCHOOL OF CORRESPONDENCE AT ARMOUR INSTITUTE OF TECHNOLOGY CHICAGO, ILL.		TYPE. INSIDE PLUNGER.	
LIST OF CASTINGS					
FOR 16-81-12 DUPLEX PUMP.					
No. Wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
2	Steam Cylinder	G		C. I.	R. & L.
2	Steam Cylinder Head	G		C. I.	
2	Steam Chest	F		C. I.	
2	Steam Chest Cover	F		C. I.	
2	Slide Valve	F		C. I.	
1	Steam Pipe	F		C. I.	
1	Exhaust Tee	F		C. I.	
2	Valve Steam Gland	F		C. I.	
2	Piston	E		C. I.	
8	Piston Pipe Plug, 1 1/2"	E		C. I.	
4	Piston Packing Ring	E		C. I.	
2	Spool	E		C. I.	
1	Steam Cylinder Cricket	L		C. I.	
2	Steam Cylinder Stuffing Box	L		C. I.	
2	Water Cylinder Stuffing Box	L		C. I.	
4	Piston Rod Gland	L		C. I.	
1	Valve Lever Bracket	L		C. I.	
2	Yoke	L		C. I.	R. & L.
1	Short Rocker Arm	K		C. I.	
1	Long Rocker Arm	K		C. I.	
2	Valve Stem Link	K		C. I.	
1	Water Cylinder	J		C. I.	
2	Water Cylinder Head	J		C. I.	
3	Hand Hole Cover	J		C. I.	
1	Water Cylinder Cap	I		C. I.	
1	Air Chamber	I		C. I.	
1	Discharge Ell	I		C. I.	
2	Plunger	H		C. I.	
2	Plunger Bushing	H		Brass	
2	Clamp Ring	H		C. I.	
32	Valve Stem	H		Brass	
32	Valve Cover	H		Brass	
32	Valve Seat	H		Brass	
6	Foundation Plate	M		C. I.	

DATE. MAY 20, 1902.		AMERICAN SCHOOL OF CORRESPONDENCE AT ARMOUR INSTITUTE OF TECHNOLOGY CHICAGO, ILL.		TYPE. INSIDE PLUNGER.	
LIST OF STEEL AND MISCELLANEOUS PARTS					
FOR					
16-8½-12 DUPLEX PUMP.					
No. Wanted.	Name.	Drawing No.	Part. or Piece No.	Material.	Remarks.
2	Valve Steam Head	E		St.	Drop Forging.
2	Piston Rod	E		C. R. S.	
2	Valve Stem	E		St.	
1	Long P. R. Lever	K		St.	Forging
1	Short P. R. Lever	K		St.	Forging
1	Upper Rocker Shaft	K		St.	
1	Lower Rocker Shaft	K		St.	
2	Rocker Arm Pin	K		St.	
2	Link Pin	K		St.	
1	Long P. R. Lever Key	K		St.	Drop Forging
1	Short P. R. Lever Key	K		St.	Drop Forging
2	Rocker Arm Key	K		St.	Drop Forging
32	Valve Spring	H		Brass wire	Spring Temper
32	Valve	H		Rubber	Medium

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

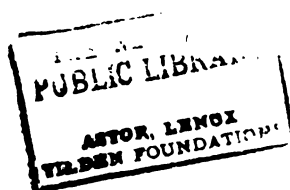
LIST OF BOLTS, NUTS AND PINS

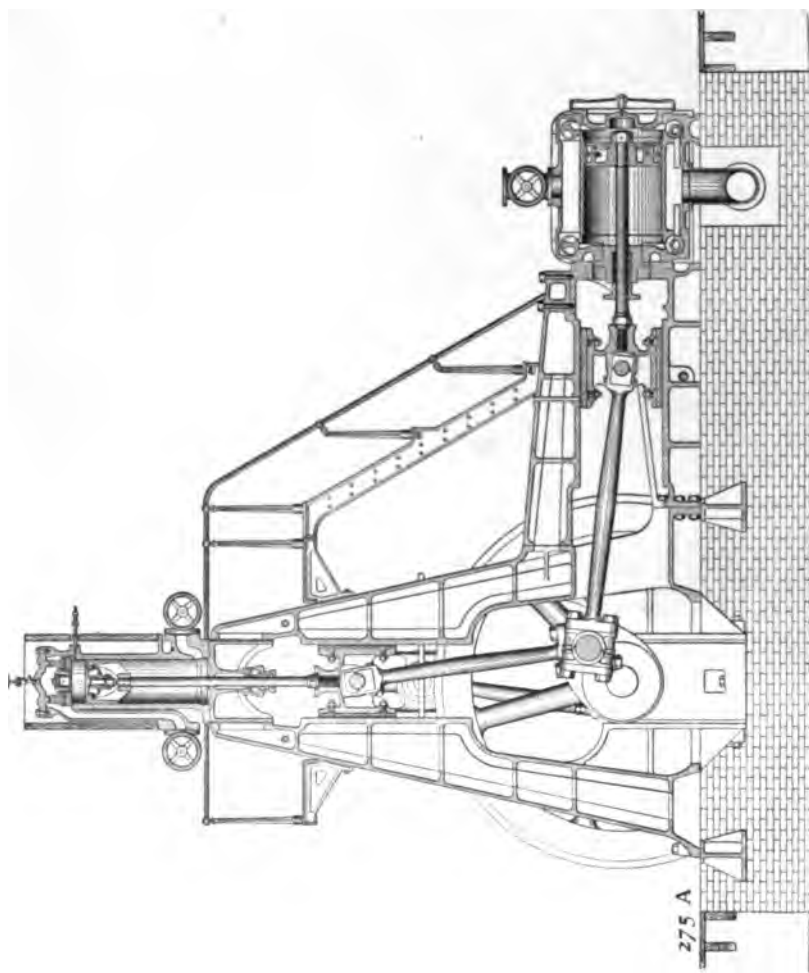
FOR

16-8½-12 DUPLEX PUMP.

No. wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
24	Cylinder Head Stud $\frac{7}{8} \times 3\frac{1}{4}$	G		St.	
20	Steam Chest Stud $\frac{3}{4} \times 8\frac{3}{4}$	G		St.	
4	Valve Stem Gland Stud $\frac{5}{8} \times 4\frac{3}{4}$	F		St.	
8	Piston Rod Gland Stud $\frac{3}{4} \times 4$	L		St.	
24	Water Cylinder Head Stud $\frac{7}{8} \times 3\frac{1}{4}$	J		St.	
12	Clamp Ring Stud $\frac{3}{4} \times 4\frac{1}{2}$	J		Tobin bz.	
24	Water Cylinder Cap Stud $1 \times 3\frac{1}{4}$	J		St.	
18	Hand Hole Cover Stud $\frac{5}{8} \times 2\frac{1}{2}$	J		St.	
12	Hand Hole Cover Stud $\frac{5}{8} \times 2\frac{1}{2}$	I		St.	
8	Exhaust Tee Tap Bolt $\frac{5}{8} \times 1\frac{3}{4}$	G		St.	
16	Yoke Tap Bolt $\frac{3}{4} \times 2$	G		St.	
8	Steam Cyl. Stf. Box Tap Bolt $\frac{3}{4} \times 1\frac{3}{4}$	G		St.	
8	Steam Pipe Tap Bolt $\frac{5}{8} \times 1\frac{1}{4}$	F		St.	
4	Valve Lever Bracket Tap Bolt $\frac{5}{8} \times 1\frac{3}{4}$	F		St.	
4	Steam Cyl. Cricket Tap Bolt $1 \times 2\frac{1}{4}$	F		St.	
16	Yoke Tap Bolt $\frac{3}{4} \times 2$	J		St.	
8	Water Cyl. Stf. Box Tap Bolt $\frac{3}{4} \times 1\frac{3}{4}$	J		St.	
8	Discharge Ell Tap Bolt $\frac{3}{4} \times 2$	I		St.	
4	Air Chamber Tap Bolt $\frac{3}{4} \times 2$	I		St.	
2	Hook Bolt (special) $1 \times 3' - 11''$	M		St.	
4	Hook Bolt (special) $1\frac{1}{4} \times 3' - 11''$	M		St.	
1	Eye Bolt Standard $1''$	I		St.	
34	Standard Nut $\frac{5}{8}$			St.	
44	Standard Nut $\frac{3}{4}$			St.	
36	Standard Nut $\frac{5}{8}$			St.	
26	Standard Nut 1			St.	
4	Standard Nut $1\frac{1}{4}$			St.	
4	Standard Nut 2			St.	
8	Special Valve Stem Nut 1			St.	$\frac{3}{4}$ Thick
4	Piston Rod Split Pin $\frac{1}{4} \times 2$	E		St.	
2	Spool Taper Pin No. 10 Morse Taper	E		St.	4" long
4	Valve Bracket Dowel Pin $\frac{1}{4} \times 2$	L		St.	

DATE. MAY 20, 1902.		AMERICAN SCHOOL OF CORRESPONDENCE AT ARMOUR INSTITUTE OF TECHNOLOGY CHICAGO, ILL.		TYPE. INSIDE PLUNGER.	
LIST OF SPECIAL FITTINGS, WRENCHES, Etc.					
FOR 16-8½-12 DUPLEX PUMP.					
No. Wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
4	Drip Cock ½"	G			
1	Drip Cock ½"	F			
2	Drip Cock ½"	L			
4	Oil Cup ½"	L			
5	Drip Cock ¾"	J			
1	Relief Valve 1½"	I			175 lbs. pressure
1	Standard Fork Wrench 1"				
1	Standard Fork Wrench ¾"				
1	Standard Fork Wrench 7/8"				
1	Standard Fork Wrench 1"				
1	Socket Wrench ¾"				12" handle
1	Valve Stem Fork Wrench				
1	Valve Stem Socket Wrench				





DIRECT DRIVEN VERTICAL AMMONIA COMPRESSOR SINGLE ACTING.

AIR COMPRESSORS

The various practical applications of compressed air cover a range of pressure from a fraction of an ounce to several thousand pounds per square inch. To produce the required supply of air with proper pressure and economy, numerous types of compressors, each having its peculiar and appropriate field, have been designed. These are, in the order of the pressure produced:—the disc fan, the centrifugal blower, the positive blower, the blowing engine, the direct-acting compressor, and the compressor with crank and fly-wheel. By the operation of all these, the same result is produced—the delivery of a quantity of air under an increased pressure and correspondingly increased temperature, and the subsequent rapid loss by the air of its excess of temperature, with a proportionate decrease in volume. Most of the problems in the design of compressors are created by the heating of the air during compression and by the effects so produced upon the apparatus.

The Disc Fan, corresponding to the marine screw propeller in action, is useful for producing a flow of air of considerable volume but with almost inappreciable increase of pressure. It is thus suitable for purposes of ventilation in expelling foul air, gases, or smoke, or for removing dust, fine shavings, and waste particles from woodworking and grinding machines. The power expended in revolving the fan goes in great part towards whirling the air current around in the fan casing and pipe—a waste of effort which limits the application of this device to conditions of moderate speed and very light pressure.

The Centrifugal Blower. By taking advantage of the tendency of revolving particles to fly away at a tangent, a fan blower of better



Disc Fan.

efficiency and a wider field of usefulness is afforded. Particles of air whirled around by the blades of the disc fan merely fly out and press against the casing; but the centrifugal blower converts this action into useful compression through the provision of a spiral casing around the fan, in which the air whirled off by the blades of the fan is deflected and conducted into a discharge pipe leading off from the casing. The blower therefore consists of a fan with radial or sometimes curved blades which stand parallel to the axis instead of obliquely as in the case of the disc fan, and which revolve in a circular or spiral casing



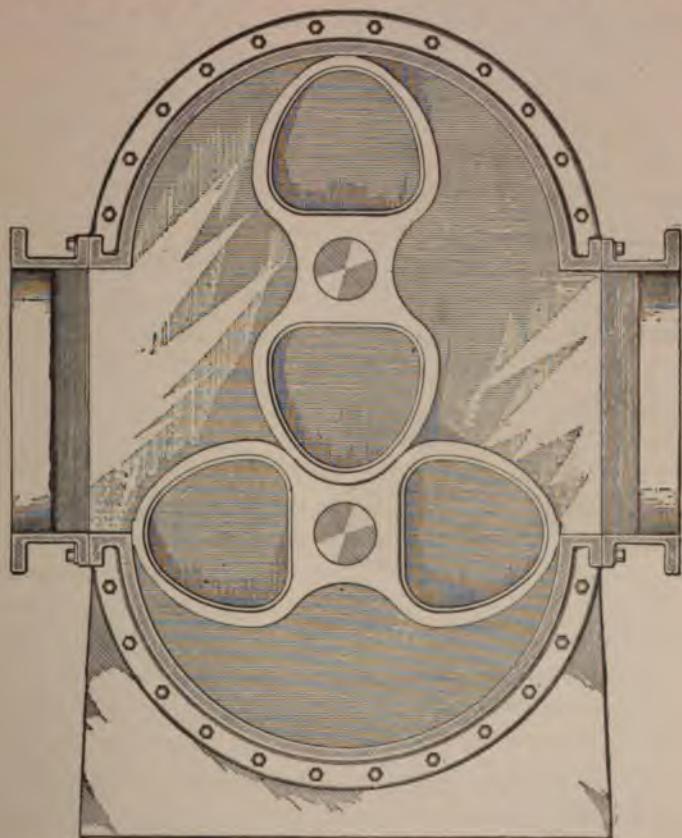
Centrifugal Blower.

surrounding the fan and opening into a large discharge pipe that leads off at a tangent in any desired direction—up, down, or sideways. Air enters around the shaft of the fan through openings in the center of the casing, and, being received by the blades, is whirled around and thrown outward into the surrounding chamber with a pressure proportionate to the square of the speed of the fan. The pressure thus produced is sufficient for blowing fires of all kinds, for removing small fragments

of wood as well as finer particles from wood-cutting machines, for delivering illuminating gas to holders, and for other purposes requiring a pressure of not much over one pound per square inch. The centrifugal blower is the most efficient contrivance known for producing these pressures, but its economy falls off very fast if the speed is made so great as to produce a pressure per square inch of much over one pound.

This machine seems peculiar in its behavior owing to the fact that it requires less power to maintain a certain speed when the discharge passage is partly closed than when it is fully open. It is evident that when there is no discharge opening, the fan, together with the air between its blades, will spin around freely like any wheel. If the dis-

charge gate be opened, air will flow about the fan blades to their outer ends, and so into the casing and thence to the pipe system; while air from the center of the fan follows out into the space between the blades, its speed increasing as it approaches the ends of the blades, whereupon it is hurled into the casing. It is the work done in accelerating the motion of these particles of air, which explains the resistance to the movement of the fan; and this work is evidently in proportion to the quantity of air that passes along the fan blades, being zero when, by



Cross-Section of Positive Blower.

reason of the closing of either suction or discharge opening, no air is discharged, and being greatest when, with full opening, the volume of air passing is the maximum. The blades of the blower would fly in pieces before the speed could be increased sufficiently to produce an air pressure much over one pound per square inch.

An apparatus identical in principle is the centrifugal pump, which, handling far heavier fluids, produces by centrifugal action pressures measured by pounds instead of ounces.

The Positive Blower. In direct competition with the centrifugal fan is the positive blower. Consider a fan having opposite blades, revolving in a closed casing, and carrying around with it the air confined between the blades. If a radial partition could be slipped in just after one of the blades had passed, the following blade would compress the air between it and the partition, and would force it out through a discharge pipe if one were provided near the supposed partition. This partition might be imagined to be momentarily withdrawn as each blade passed, so that successive portions of air would be trapped and compressed. The positive blower consists of a fan of this sort, with one or more blades, revolving in connection with an "abutment" performing the office of the partition just alluded to. A well-known form consists of a cylinder carrying two radial blades, and revolving in contact with a cylinder of half the diameter which is provided with a gap of proper form to receive the passing blades. As each blade travels around the casing, it drives the air before it up to the smaller cylinder, whose gap comes around at the proper instant to allow the blade to pass, while intercepting the air continuously.

The Air Compressor is a cylinder-and-piston machine like the common steam engine. It comprises two sets of valves, usually designed to be opened automatically by excess of pressure under them and to be closed by gravity or by the action of springs when the pressures become equal. The inlet valves open just after the piston commences its stroke, when the expansion of the compressed air remaining in the cylinder behind the piston has lowered the pressure above the valves. They close at the end of the intake stroke, just as the piston comes to rest. The outlet valves lift during the compression stroke, at about the time the rising pressure in the cylinder becomes equal to that in the outlet passage above the valves; and they close when the flow of air ceases as the piston completes its stroke.

Perfectly correct action of automatic valves is not realized in practice. The valve must evidently be larger than the opening in its seat, so that the upper surface is larger than the area underneath reached by the lower pressure; consequently the valve will not open until the pressure below is greater than that above. To prevent de-

structive slamming of the valves, springs must be provided to force them to their seats just as the flow ceases and before the reverse stroke of the piston can cause much backward flow of air. The pressure of the springs acts to choke the flow through the valves, increasing the resistance they offer to the passage of air. Large compressors are therefore often provided with mechanically-actuated valves which are opened and closed smoothly at the proper moment by eccentrics and valve rods. Any of the steam-engine valve gears may be used for compressors, and designed by the same methods, observing only that the compressor is in every way a reversed steam engine, so that its discharge port and valves are duplicates of the inlet details of the engine, while the engine exhaust and the compressor inlet valves are also similarly related.

Varying initial (or boiler) pressure is compensated, except in throttling engines, by varying time of inlet-valve closure or "cut-off;" and varying discharge pressure in a compressor calls for variation in time of opening of the discharge valves. In both cases, the means of variation constitute the chief problem for the designer.

Mechanically-moved inlet valves of compressors act always at the same points, opening a trifle after the piston starts on the intake stroke, and closing exactly at the end of the same stroke; but the discharge

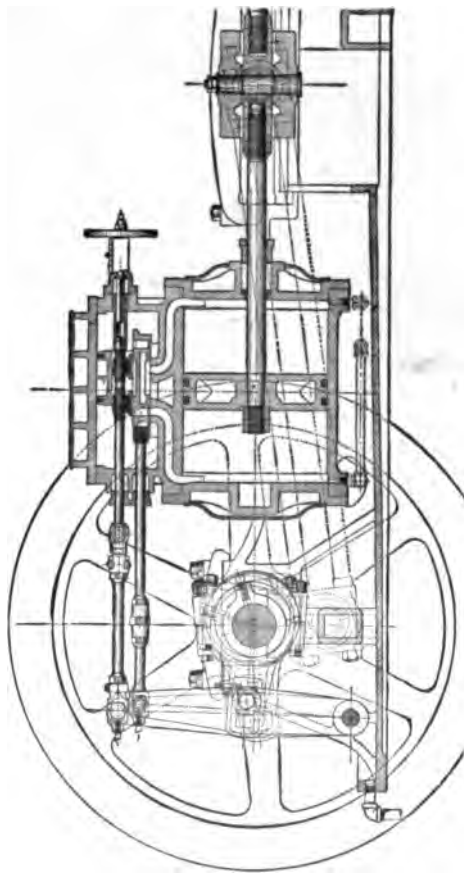


Air Compressor.

valves must open at the instant the piston has compressed the air in front of it to a pressure equaling that above the valves in the discharge pipe, and must close always at the same instant, at the end of the stroke. As the compressor may be working against a pressure greater or less than that regularly carried, the discharge valves must be so controlled as to open at whatever point is required by the pressure then being

carried. The requirements are sometimes met by putting automatic lift-valves above, or even directly upon, the mechanical discharge valves, giving the combination the effect of valves automatic as regards their opening, but positively closed by the mechanism at the proper instant. Such lift-valves, being shut off entirely at the proper closing instant, seat themselves without noise or shock, and may therefore have very light springs, causing less resistance to the air passing through.

Where the expense of full mechanical action is warranted on account of the superior efficiency obtainable, poppet or

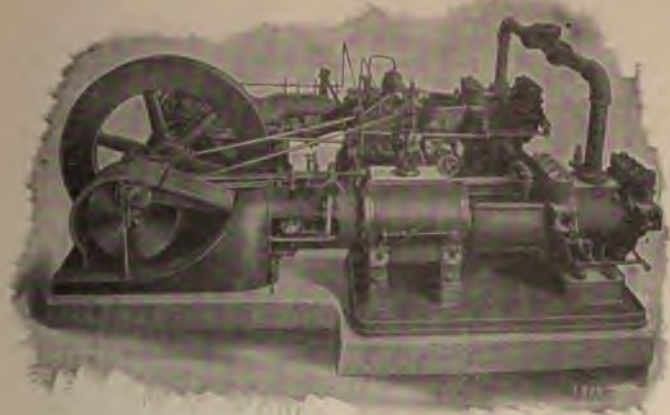


Sectional View of Steam Cylinder of Air Compressor.

rotary valves may be arranged to open by means of springs or air dash-pots. The opening device is released either through the rising pressure in the cylinder easing the valve on its seat, and reducing the friction until the valve, when balanced, slips freely open; or through the same pressure acting on a piston attached to a pusher, the operation of which results either in starting the valve in spite of friction or in lift-

ing a catch and thereby freeing the spring or dashpot mechanism of the compressor.

Compound Compressors. While low-compression pressures are accompanied by only moderate heating of the air during compression, the production of high pressures is attended with excessive heat and considerable increase in the volume of the compressed air. As the air leaving the cylinder soon resumes the normal temperature, and decreases in volume accordingly, the extra work done in compressing the increased volume is wasted. Compressing cylinders in operation are always cooled by water or otherwise; but it is impossible, even by spraying water into the cylinder, to keep the air from rising consider-

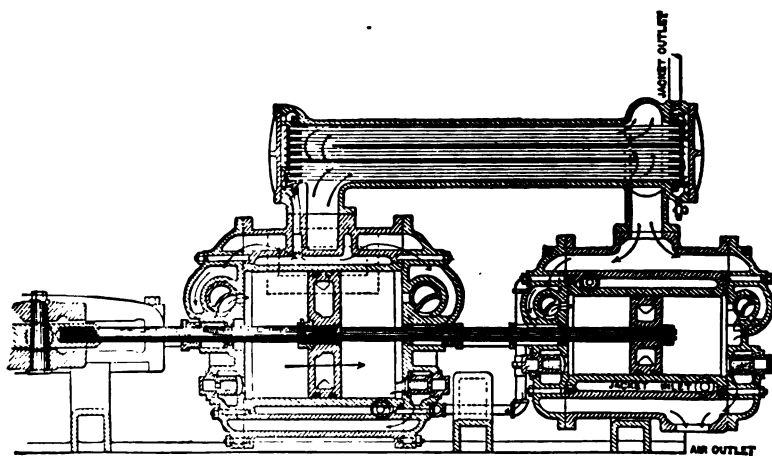


Cross Compound Duplex Air Compressor.

ably in temperature. For high pressures, resort is therefore had to compound compression, the air being passed successively through larger low-pressure to smaller high-pressure cylinders, between which are located inter-coolers whose function is to restore the air to its original temperature before it enters on the next stage. The volume of the air is thus kept as small as possible; and the successive stages of compression result in producing the required pressure, with a minimum of loss from heating during the process. Two-stage machines are preferred to single-stage where air must be compressed to one-sixth or a greater fraction of its volume at atmospheric pressure (measuring pressures from absolute vacuum); and three or more stages are required in compressing to less than one-sixth. Cylinder diameters are

selected which will provide for about the same amount of work being done in each cylinder.

Most compressor problems deal with air taken directly from the atmosphere at its sea-level pressure; but, as at moderate elevation there is a marked decrease of the atmospheric pressure, compressors for high locations must deal with air at pressures below fifteen pounds absolute. Under such conditions the volume of air taken into the compressor at each stroke weighs less, and therefore less air is delivered by the compressor, while there is a corresponding decrease in the power to run the



Sectional View of Air Cylinder and Inter-Cooler.

machine. The ratio of compression, and the rise in temperature, are proportionately increased, so that a two-stage compressor may be desirable for pressures that would call for only single cylinders at sea-level. Thus, at many of the mines in the Rocky Mountain region, the atmospheric pressure is as low as eleven pounds per square inch, so that 90 pounds' air pressure by gauge requires a compression ratio of nine to one, which is considerably beyond that proper for a single-stage compressor. In general, high-level compressors should be specially proportioned for their work.

Methods of Driving. Like pumps and other machinery, compressors are direct-connected to engines or are driven through gears or belts from separate sources of power. The reciprocating piston compressor requires a varying effort to balance the cylinder pressure, since, during the stroke, the piston moves against an increasing air pressure,

and finally against the full discharge pressure, in pushing out the contents of the cylinder. Direct-connected compressors are either "straight-line" (tandem), having steam and air pistons on the same piston rod, or they are connected to cranks set at an angle on a common shaft. The first method reduces floor space and cost, but requires very heavy fly wheels, and makes the machine liable to stop on a center if run much below full speed and capacity.

It is evident that steam used expansively supplies against the piston a force decreasing toward the end of the stroke, while air during compression opposes a force increasing towards the end of the stroke; thus the power rapidly falls off as the resistance increases, causing a perceptible reduction in speed at the end of each stroke. If such a machine could be run at high speed, the weight (or more correctly, the mass) of the pistons and connections would, by in-



Portable Motor-Driven Compressor.

ertia, help out the decreasing steam pressure when slowing to pass the centers, and thus produce a more even effort on the crank; but sufficiently high speeds are not possible for the automatic-lift valves

generally used on small compressors. The varying power and resistance can be very satisfactorily balanced by connecting steam and compressing pistons to separate cranks set at right angles. Having provided two frames and cranks, a slight additional outlay will supply an extra pair of cylinders tandem to the first pair, making a full duplex compressor. The excess steam pressure at the commencement of the stroke of one side is here transmitted by the crank shaft to the other side of the machine, to help out the deficient pressure of the expanded steam when the stroke is nearly finished. Such a machine has no "dead centers," and can be run at very slow speed when necessary.

As it is generally desirable to maintain a constant air pressure, and to vary the speed of the machine according to the quantity of air required, speed governors for the steam cylinders are not needed except to prevent racing in case of a bursting pipe or other excessive discharge of air. Some form of adjustable cut-off valves is very desirable in order to allow of suiting the work of the steam cylinder to the load. The pressure is controlled by automatic devices actuated by the rise and fall of the air pressure, either shutting off the air intake, opening a by-pass around the compressor piston, or (in case of duplex machines which can start from rest without attention) shutting off steam and stopping the machine.

A description of the standard types of commercial compressors would be incomplete without reference to the most remarkably wasteful "steam eater" known to the compressor trade—a machine using ten times as much steam as would be necessary for pumping the same amount of air by means of a fairly economical compressor, and yet a device most ingenious and entirely satisfactory for its work. This is the air-brake pump, which, for actual conditions of train service—where it stands idle until the closing of the throttle and the application of brakes leave a large and heavily fired steam boiler to blow off at the safety valve until the fire can be checked—is seen to be well adapted. Indicator cards show that the entering steam is throttled through about half the stroke, while the exhaust is similarly choked at first and only let out freely about the time of full opening of the valve. The result is a "straight-line" compressor having no crank or fly wheel, with nothing moving but its two pistons and one rod, and yet so perfectly balanced between effort and resistance that its strokes are smoothly made at any speed from slowest to fastest, and all with max-

imum simplicity and minimum weight. These machines are also built with compound steam and two-stage air cylinders, and in these cases have pressures in the cylinders so nearly uniform that the steam distribution may be considerably more economical than it is possible to obtain in the single-stage compressor.

The selection of general types and special details for compressors must be based, as in all other cases of machine design, on the practical condition of getting the best return from the money invested, with due regard to the importance of reliability and durability in each particular case.



REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

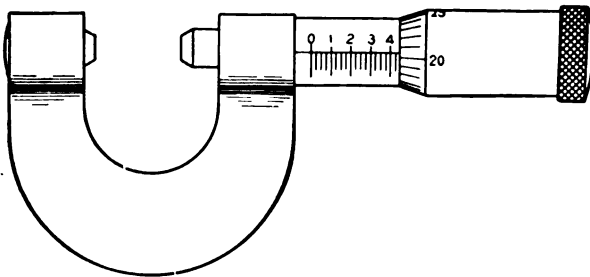
In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS
ON THE SUBJECT OF
MACHINE SHOP WORK.

PART I

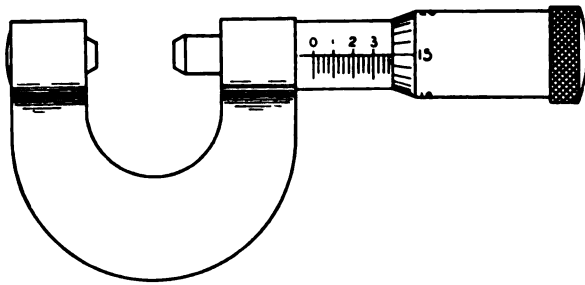
1. What are limit gauges?
2. When are calipers used? and how are they set?
3. If there are 40 threads per inch on the micrometer screw, what is the reading of this micrometer?



4. What is a soft hammer, and when is it used?
5. What is a chuck drill?
6. What methods are used for cleaning a file?
7. How should a file be held for fine filing?
8. Describe the surface gauge.
9. Describe the micrometer caliper.
10. Describe two common forms of chisel, and state under what conditions they are used.
11. Why is not the cutting surface of a file perfectly flat?

MACHINE SHOP WORK.

12. Give the reading of the micrometer caliper when in the position shown.

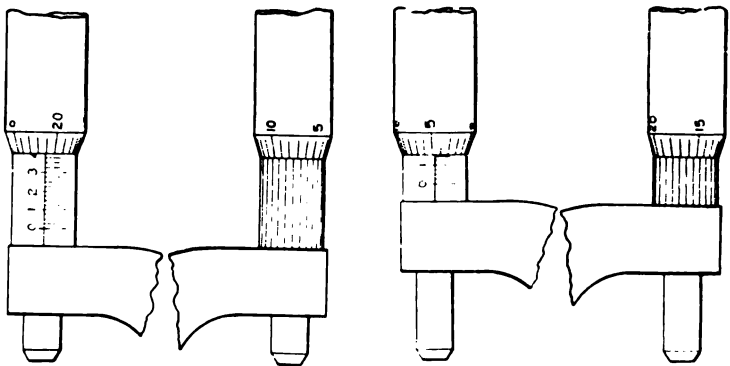


13. What methods are used for holding a file for filing large surfaces?

14. Describe the twist drill.

15. What is a vernier?

16. What is the reading of the vernier micrometer caliper when in the positions shown?



17. What is the result when the lips of the twist drill are of unequal length?

18. When are reamers used?

19. How much less should the diameter of the drilled hole be than finish size if a reamer is to be used?

20. Explain the methods of cutting screw threads with a die.

21. What advantage has an adjustable reamer over a solid reamer?

REVIEW QUESTIONS
ON THE SUBJECT OF
MACHINE SHOP WORK.

PART II

1. What is a mandrel?
2. Describe the rise-and-fall rest.
3. How long will it take to turn a chip 18 inches on a shaft 24 inches long and $3\frac{1}{4}$ inches in diameter?
Assume cutting speed 20 feet per minute.
Assume feed $\frac{1}{50}$ inch per revolution.
4. Describe the process of making a taper fit.
5. The lead screw has a pitch of $\frac{1}{4}$ inch. What is the ratio of gears to be used to cut a screw with 18 threads per inch?
6. Describe the process of bringing the countersink back to center.
7. For what purpose is the back gear of a lathe?
8. Describe some method of adjusting pieces to center.
9. Describe the shapes, and state the uses of the following lathe tools: Diamond point, side or facing tool, parting tool, and square-nosed tool.
10. Why are lubricants used in turning?
11. Describe the method for finding the clearance for a tool for cutting square threads.
12. On account of not having the proper gears at hand compound gears must be used. The lead screw has 4 threads per inch, and a screw having 9 threads per inch is to be cut. The gears chosen for drivers are of 24 teeth on the spindle gear and 30 on the intermediate. What gear should be used for the intermediate driven if the screw gear has 60 teeth?

MACHINE SHOP WORK.

13. Describe the U.S. Standard thread.
14. Describe the steady rest.
15. How would you adjust a piece to center if the hole must be run true?
16. Why should a boring tool have more clearance than a turning tool? Explain with sketch.
17. Explain the method of turning a taper by setting the tailstock over.
18. In what direction does the carriage run when cutting a right-hand thread?
19. A screw of 14 threads is to be cut in a lathe having a lead screw of 3 threads per inch. Compound gears are to be used. The gears available have 20, 30, 40, 50, 60, 70, and 80 teeth. What ones are to be used and where?
20. How is motion transmitted from the cone pulley of a drill press to the drill?
21. How is motion transmitted from the spindle to the lead screw?
22. Describe clearance and rake as applied to a lathe tool. Give approximate values in degrees for cutting steel.
23. Should a tool for turning brass have rake? Why?
24. The end of a piston rod is to be turned tapering. The piston rod is 28 inches long; the tapered portion is to be 3 inches long. The diameters of the taper are to be $2\frac{3}{4}$ inches and $2\frac{1}{4}$ inches. How much must the tail block be set over?
25. Suppose the lead screw of a lathe has 4 threads per inch and we wish to cut 11 threads per inch. The gear on the spindle has 20 teeth. What gear should be chosen for the lead screw?
26. What is a universal radial drill?
27. In what ways is a twist drill preferable to a flat drill? How is the drill made to turn with the spindle?
28. Describe the universal chuck.
29. Why should not a tool be set too high?
30. How long will it take to turn a chip from a shaft 4 inches long $5\frac{1}{2}$ inches in diameter?
Assume cutting speed 23 feet per minute.
Assume feed of $\frac{1}{32}$ inch per revolution.

REVIEW QUESTIONS
ON THE SUBJECT OF
HEATING AND VENTILATION.

PART I.

1. What advantage does indirect steam heating have over direct heating? What advantages over furnace heating?
2. What are the causes of heat loss from a building?
3. Why is hot water especially adapted to the warming of dwellings?
4. What proportion of carbonic acid gas is found in outdoor air under ordinary conditions?
5. A room in the N. E. corner of a building is 18' square and 10' high; there are 5 single windows, each 3' $\times$ 10' in size. The walls are of brick 12" in thickness. With an inside temperature of 70 degrees what will be the heat loss per hour in zero weather?
Ans. 21,447 B. T. U.
6. State four important points to be noted in the care of a furnace?
7. A grammar school building has 4 rooms, one in each corner, each being 30' $\times$ 30' and 14' high and seating 50 pupils. The walls are of wooden construction and the windows make up $\frac{1}{3}$ of the total exposed surface. The basement and attic are warm. How many pounds of coal will be required per hour for both heating and ventilation in zero weather if 8000 B. T. U. are utilized from each pound of coal?
Ans. 96.3 lbs.
8. What two distinct types of furnaces are used? What are the distinguishing features?
9. What is meant by the efficiency of a furnace? What efficiencies are obtained in ordinary practice?
10. What are the principal parts of a furnace? State briefly the use of each.
11. A brick house 20' $\times$ 40' has 3 stories, each 10' high.

HEATING AND VENTILATION.

The walls are 12" in thickness and $\frac{1}{4}$ the total exposed wall is taken up by windows, which are double. The basement is warm, but the attic is cold. The house is to be warmed to 70 degrees when it is ten degrees below zero outside. How many square feet of grate surface will be required, assuming usual efficiencies of coal and furnace? Ans. 8.5 square feet.

12. A high school is to be provided with tubular boilers. What H. P. will be required for warming and ventilation in zero weather if there are 600 occupants, and the heat loss through walls and windows is 1,500,000 B. T. U. per hour? Ans. 114.8

13. What are the three essential parts of any heating system?

14. Is direct steam heating adapted to the warming of schoolhouses and hospitals? Give the reasons for your answer.

15. The heat loss from a dwelling house is 280,000 B. T. U. per hour. It is to be heated with direct steam by a type of boiler in which the ratio of heating surface to grate surface is 28. What will be the most efficient rate of combustion, and how many square feet of grate surface will be required? Ans. 7 pounds. 5 sq. feet.

16. What is the use of a blow-off tank? Show by a sketch how the connections are made.

17. How are the sizes of single pipe risers computed?

18. What weight of steam will be discharged per min. through a 6" pipe 300' long with an initial pressure of 10 pounds and a drop of $\frac{3}{4}$ pound in its entire length?

19. What is an air valve? Upon what principles does it work?

20. What size of steam pipe will be required to discharge 2400 pounds of steam per hour a distance of 900', with an initial pressure of sixty pounds and a drop in pressure of 5 pounds? Ans. $3\frac{1}{2}$ dia.

21. What objection is there to a single pipe riser system? How is this sometimes overcome in large buildings?

22. What patterns of valves should be used for radiators? What conditions of construction must be observed in making the connections between the radiator and riser?

HEATING AND VENTILATION.

23. The heat loss from a shop is 36,000 B.T.U. per hour; how many linear feet of 2" pipe will be required to warm it, using low pressure steam? Ans. 192 feet.

24. What are meant by "wet" and "dry" returns? Which is the better, and why?

25. How many linear feet of 1½" pipe are required to give off the same amount of heat as a cast iron radiator having 125 square feet of surface? Ans. 215 feet.

26. What three systems of piping are commonly used in direct steam heating? Describe each briefly.

27. What is a "branch coil?" What is a "trombone coil?" In what cases would you use a trombone coil instead of a branch coil?

28. What is meant by the efficiency of a radiator? Give average efficiencies of cast iron and pipe radiators, also circulation coil.

29. The heat loss from a room is 22,500 B.T.U. in zero weather. What size of cast iron radiator would be required to warm the room when it is twenty degrees below zero?

Ans. 128 square feet.

30. Where would you place the direct radiation in a school-room?

REVIEW QUESTIONS
ON THE SUBJECT OF
HEATING AND VENTILATION.
PART II.

1. How would you obtain the sizes of the cold and warm air pipes connecting with indirect heaters in dwelling-house work?

2. What is an aspirating coil and what is its use?

3. What efficiencies may be allowed for indirect heaters in schoolhouse work? How would you compute the size of an indirect heater for a room in a dwelling house?

4. How is the size of a direct-indirect radiator computed?

5. A schoolroom on the fourth floor is to be supplied with 2,400 cubic feet of air per minute. What should be the area of the warm-air supply flue?

Ans. 6 square feet.

6. What is the chief objection to a mixing damper, and how may this be overcome?

7. How many square feet of indirect radiation will be required to warm and ventilate a schoolroom when it is 10 degrees below zero, if the heat loss through walls and windows is 42,000 B. T. U. and the air supply 120,000 cubic feet per hour?

Ans. 349 square feet.

8. What is the difference in construction between a steam radiator and one designed for hot water? Can the steam radiator be used for hot water? State reasons for answer.

HEATING AND VENTILATION.

9. How may the piping in a hot water system be arranged so that no air valves will be required on the radiators?

10. What efficiency is commonly obtained from a direct hot water radiator? How is this computed?

11. How should the pipes be graded in making the connections with indirect hot water heaters? Where should the air valve be placed?

12. Describe briefly one form of grease extractor.

13. What is the office of a pressure reducing valve in an exhaust steam heating system?

14. Upon what principle does a pump governor operate?

15. What type of pipe fittings should always be used in hot water work?

16. How is the water of condensation returned to the boilers in exhaust steam heating?

17. How many cubic feet of air per hour will be discharged through a flue 2 feet by 3 feet and 60 feet high, if the air in the flue has a temperature of 80 degrees and the outside air 60 degrees?

Ans. 134,280 cubic feet.

18. In a hot water heating system what causes the water to flow through the pipes and radiators? How does the height of the radiator above the boiler effect the flow?

19. What precaution should always be taken before starting a fire under a steam boiler?

20. What is the free opening in square feet through a register 24 inches by 48 inches? Ans. 5.3 square feet.

21. Why are return pumps or return traps necessary in exhaust steam heating plants?

22. What efficiency may be obtained from indirect hot water radiators under usual conditions? What is the common method of computing indirect hot water surface for dwelling house work?

23. State briefly how a return trap operates.

24. What is the use of an expansion tank, and what should be its capacity?

25. Describe the action of one form of damper regulator.

HEATING AND VENTILATION.

26. What is the principal difference between a hot water heater and a steam boiler? What type of heater is best adapted to the warming of dwelling houses?

27. Upon what four conditions does the size of a pipe to supply any given radiator depend?

28. What is the use of an exhaust head?

29. A hospital ward requires 60,000 cubic feet of air per hour for ventilation, and the heat loss through walls and windows is 140,000 B. T. U. per hour. How many square feet of indirect radiation will be required in zero weather?

Ans. 491 sq. ft.

30. For what purpose is a back-pressure valve used?

31. A hospital ward is warmed by direct heat and it is desired to add ventilation by using indirect radiators for warming the air supply. The ward has 20 occupants. How many square feet of indirect surface will be required when it is 10 degrees below zero, allowing an efficiency of 60%?

Ans. 211 sq. ft.

32. A first floor classroom in a high school had 40 pupils, how many square feet area should the vent duct have?

Ans. 5.8 sq. ft.

33. A private grammar school room having 15 pupils is heated by indirect hot water. It is decided to increase the size of boiler and introduce ventilation by means of indirect hot water radiation. How many more square feet of grate surface will be required in the new boiler for zero weather?

REVIEW QUESTIONS
ON THE SUBJECT OF
HEATING AND VENTILATION.

PART III.

1. A main heater contains 1,040 square feet of heating surface made up of wrought iron pipe, and is used in connection with a fan which delivers 528,000 cubic feet of air per hour. The heater is 20 pipes deep and has a free area between the pipes of 11 square feet. If air is taken at zero, to what temperature will it be raised with steam at 5 pounds pressure?

Ans. 140°.

2. A nine-foot fan running at 130 revolutions delivers 40,000 cubic feet of air per minute. If the fan is speeded up to 169 revolutions, and an electric motor substituted for the engine, what will be the rating of the required motor?

3. What precaution must be taken in connecting the radiators in tall buildings.

4. Give the size of heater from Table II, which will be required to raise 672,000 cubic feet of air per hour, from 10° below zero to 90°, with a steam pressure of 20 pounds. If the air quantity is raised to 840,000 cubic feet per hour through the same heater, what will be the resulting temperature with all other conditions the same?

Ans. 85.5°.

5. A fan running at 150 revolutions produces a pressure of $\frac{1}{2}$ ounce. If the speed is increased to 210 revolutions, what will be the resulting pressure?

6. A certain fan is delivering 12,000 cubic feet of air per minute, at a speed of 200 revolutions. It is desired to increase the amount to 18,000 cubic feet. What will be the required

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speed? If the original power required to run the fan was 4 H. P., what will be the final power due to the increased speed?

7. What size fan will be required to supply a schoolhouse having 300 pupils, if each is to be provided with 3,000 cubic feet of air per hour? What speed of fan will be required, and what H. P. of engine?

8. What advantages has the plenum method of ventilation over the exhaust method?

9. A church is to be warmed and ventilated by means of a fan and heater. The air supply is to be 300,000 cubic feet per hour. The heat loss through walls and windows is 200,000 B. T. U., when it is 10° below zero. How many square feet of heating surface will be required, and how many rows of pipe deep must the heater be with steam at 5 pounds pressure?

Ans. 14 rows.

10. A schoolhouse requiring 600,000 cubic feet of air per hour is to be supplied with a cast iron sectional heater. How many square feet of radiating surface will be required to raise the air from 10° below zero to 70° above, with a steam pressure of 20 pounds?

Ans. 528 square feet.

11. What velocities of air-flow in the main duct and branches are commonly used in connection with a fan system?

12. A main heater is to be designed for use in connection with a fan. How many square feet of radiation will be required to warm 1,000,000 cubic feet of air per hour, from a temperature of 10° below zero to 70° above, with a steam pressure of 20 pounds and a velocity of 800 feet per minute between the pipes of the heater? How many rows of pipe deep must the heater be?

Ans. 882 square feet.

13. State in a brief manner the essential parts of a system of automatic temperature control.

14. What advantage does an indirect steam heating system have over furnace heating in schoolhouse work?

15. The air in a restaurant kitchen is to be changed every 10 minutes by means of a disc fan. The room is 20 × 30 × 10. Give size and speed of fan and H. P. of motor.

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